

**The empirical relationship between the value of rupee and performance of information  
technology firms: Evidence from India**

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# **The empirical relationship between the value of rupee and performance of information technology firms: Evidence from India**

## **Abstract**

This study aims to investigate the dynamic linkage between exchange rates of Indian Rupee-US Dollar and stock prices of four Indian information technology (IT) companies. The study utilizes daily data of closing stock prices of IT companies and exchange rates for the period of August 2004 to September 2013. Empirical results of AGDCC GARCH model suggest that correlations are time-varying and are largely negatively associated over time. This indicates that there is an inverse relationship between the movements of exchange rates and the performance of IT companies. Further, cointegration test results show no significant long-run equilibrium relationship between exchange rates and stock prices of IT companies. Finally, Granger non-causality test results reveal that the null hypothesis of IT companies does not Granger cause exchange rates is strongly rejected at 5% significance level and no evidence of reverse causality is found. These findings suggest that exchange rates do not drive the performance of IT companies in India.

**JEL classification:** C22; F31; L86

**Keywords:** Exchange rates; IT companies' performance; AGDCC-GARCH model

## **1. Introduction**

Dynamic linkages between stock prices and exchange rates have received substantial amount of attention from academic researchers, economists and policy makers since the last decade. Investigation of this relationship has gained momentum particularly in the aftermath of Asian financial crisis of 1997-98 (Granger, Huang & Yang 2000; Ramasamy & Yeung 2001). In the recent years, world markets have become interdependent particularly due to acceptance of flexible exchange rate system and relaxation of controls on foreign transactions and investments. These changes have opened doors to investments in international markets, flexibility to readjust to external shocks and automatic adjustment of balance of payments. It has also increased the volatility of exchange rates and risks associated with international investments. Therefore, it is important for all market participants to understand the nature of this relationship between exchange rates and stock prices in order to make cautious investment decisions.

This paper develops around the relationship between Indian Rupee - US Dollar exchange rate and performance of information technology (IT) firms of India. India's exchange rate policy underwent a shift from fixed exchange rate system to floating exchange rate system in 1993. This change has increased the volatility of Rupee with respect to Dollar, especially in recent periods. Generally, a nation with appreciating currency is perceived as a strong nation while that with a depreciating currency is considered less attractive (see, Gould and Kamin, 2001). After Asian financial crisis 1997-98 and global financial crisis 2007-08, policy makers in many countries are not concerned with currency depreciation since it helps to improve market share of exports and relaxes monetary conditions, see Tsai (2012) for a detailed explanation. Similar is the case of Indian IT industry which is a major exporter of software and solutions to the US. Thus, most IT companies' experience monetary gain when Rupee weakens against US dollar. This is in line

with the traditional economic theory which states that movements in exchange rates lead to movements in stock prices. It proposes a positive correlation between exchange rates and stock prices. Therefore a weaker Rupee is good for India's IT sector. But this relationship is beneficial to India only in short and medium-term. In long term, a depreciating Rupee is a matter of concern because it increases the cost of imports and utilities thereby increasing the price of foreign products or services (Yang et al., 2014). It may also affect accumulated foreign exchange payment obligations of IT companies (Prasad and Panduranga Reddy, 2009).

Although the traditional economic view perceives a causal relationship from exchange rates to stock prices, empirical evidence provides contradictory results varying from reverse causality, bidirectional causality to no causality. Our study aims to understand the relationship between exchange rates and stock prices from the standpoint of India's IT industry. This is an important issue to be addressed as the performance of IT firms has significant impact on the Indian economy. For instance, healthier performance of IT companies provides high-salary job opportunities which indirectly creates enormous employment opportunities and raises the income level. Therefore, it is important to understand their relationship. For example, if there is a causal relationship between the two variables and it runs from exchange rates to stock prices, then downturn in the Indian IT industry, in form of increasing cost of imports and utilities, can be averted and controlled by keeping an eye on Dollar-Rupee exchange rates but if there is an opposite relationship between the two variables, then IT firms can focus on domestic policies and reforms to stabilize their performance. To the best of our knowledge there is no study which has investigated the relationship between exchange rates and stock prices of Indian IT companies.

This paper aims to examine the dynamic relationship between the value of Rupee and performance of Indian IT companies. Understanding the nature and direction of causal relationship between exchange rates and stock prices is important for IT companies as it will assist them to manage their exposure to foreign contracts. This study also has important implications for policy makers and the investment community. It is common to include cash as an asset in the investment portfolio especially in the case of professionally managed portfolios. Therefore, an understanding of the relationship between exchange rates and stock prices may equip portfolio managers to handle currency risk in a competent manner. Empirical literature argues that currency was one of the main sources for the Asian Financial Crisis in 1997. Sharp depreciation of the Thai Baht is believed to trigger depreciation of other East Asian currencies, Brazil and Russia which eventually led to demise of Asian stock markets (Khalid and Kawai, 2003). Awareness about relationship between exchange rates and stock prices can prepare Indian IT firms in taking preventive actions before the spread of a crisis. Further, findings of this study may also be useful for other IT growing emerging economies to understand the link between exchange rates and the performance of IT firms.

Growth and development of India's IT industry has caught the attention of the world markets. Though India's domestic IT market is expanding rapidly, the most important factor that has driven this progress is its export market. The two main components of India's IT industry are IT Services and IT-enabled services (IT-ES) such as business process outsourcing (BPO). Together they have been a phenomenal success when measured against its share in India's GDP, growth in exports and employment. The industry's contribution to India's GDP has increased from 1.2% in 1998 to 7.5% in 2012 (NASSCOM, 2012). India's GDP is expected to grow from 4.7% in 2012 to 6.4% in 2014 (World Bank, 2015) in which the IT industry's contribution is around 40% of

the country's GDP growth. The IT industry contributes 14% of total India's exports. Exports dominate the industry and account for 77% of the total industry's revenue. History of India's IT exports dates back to 1970's when TATA Consultancy was established. It was only during this time when India started exporting its IT services in the foreign market. The subsequent devaluation of the Indian rupee in 1991, which led to liberalisation of government policies, and the introduction of Special Economic Zone (SEZ) policy in April 2000 made it possible for India's IT industry to grow at an accelerated pace. The main objective of this policy was to boost economic growth, attract foreign investments into India and to provide an environment for international exports that was easy and hassle-free (Lateef, 1997). Since then India's IT service exports has increased from 31.9% in 2000 to 47.0% in 2010. According to Nasscom, in 2012 the industry's total revenue was \$100 billion, of which revenues from exports stood around at \$69 billion and domestic revenues were about \$31 billion. India's software exports are expected to increase by 13-15% in the next fiscal year 2015. In Dollar terms, it is expected to rise from \$86 billion as of March 2014 to \$99 billion. They have also estimated that the overall Indian IT industry is expected to grow to about \$300 billion by 2020 (NASSCOM, 2012). This industry is considered to be an employment generator, providing employment directly and indirectly to about 11.5 million people in the country. The above data shows the increasing importance of IT sector's role in Indian exports. This sector is also generally perceived to be the sector that has led economic growth in India.

The leading role of this sector in Indian economy provides primary motivation for this study. We therefore examine the dynamic linkage between the value of Rupee and performance of four Indian IT firms (HCL, INFOSYS, TATA and WIPRO) over the period from 2004 to 2013. These IT companies are the largest IT firms in India and represent more than 50% of market

capitalization of IT firms listed in Indian stock markets. In order to determine the time-varying relationship between exchange rates and stock prices, we use the Asymmetric Generalized Dynamic Conditional Correlations (AGDCC) model. Our results suggest that movements between exchange rates and stock prices are negatively associated. Going further, we examine the long-run relationship between these variables using cointegration methodology. Cointegration test results show no significant long-run equilibrium relationship among these variables. In the third and final step, we determine the direction of causality between these variables using Toda-Yamamoto Granger non-causality test. The results reveal that causality runs from stock prices of IT companies to exchange rates. We do not find any reverse or bi-directional causality. Our results are consistent with the portfolio balance approach (Branson et al., 1977; Hatemi-J and Irandoust, 2002; Tsagkanos and Siriopoulos, 2013; Chkili and Nguyen, 2014) which hypothesis causality from stock prices to exchange rates.

The remaining paper is organized as follows. Section 2 presents brief literature survey that examines the interaction between stock price and exchange rate movements and vice-versa. Section 3 provides the details on nature of data and methodology used in the study. Section 4 discusses the empirical results and section 5 provides concluding remarks.

## **2. Literature review**

With the gradual implementation of macroeconomic reforms and liberalization of the Indian economy since the early 1990s, India's exchange rate system has evolved over time. Post-independence, India's exchange rate system has seen a shift from par value system to basket-peg system and further to a managed floating exchange rate system. Since independence until 1971, India had adopted the par value system where Indian rupee's par value was fixed against 4.15 grains of gold. During this period, in 1966, the Indian rupee began to devalue in terms of gold

which led to the reduction of par value to 1.83 grains of gold. Thereafter, it remained constant until 1971. In 1971, under the Bretton Woods agreement, Indian rupee was linked to pound sterling, but this highlighted the weakness of being associated with a single currency. To overcome this weakness and to ensure stability of the exchange rate, the rupee was pegged to a basket of currencies until the early 1990s (Dua and Ranjan, 2010).

The financial sector reforms in the early 1990s brought dramatic change in the functioning of India's financial sector. In 1993, India has adopted a flexible exchange rate system under which change in exchange rates is determined by market demand and supply for currencies and is more frequent than that in a fixed exchange rate system. These frequent changes in exchange rates can be attributed to changes in demand and supply of currencies that would have an impact on stock prices of both countries. A reverse relationship between the two variables is also anticipated. In this paper we attempt to determine the nature of relationship between Rupee-Dollar exchange rates and stock prices of Indian IT industry.

The traditional economic theory suggests that stock prices serve as discounted present value of a firm's expected future cash flows and therefore any impact of the firm's cash flows will affect its stock price in an efficient market. Thus, when a country's currency depreciates, it makes their exports more attractive and competitive which leads to an increase in stock prices. According to this approach, there is a causal and unidirectional relationship from the exchange rates to the stock prices (Tsai, 2012). Aggarwal (1981) documents this relationship between exchange rates and stock prices. He studied the impact of floating exchange rates on stock prices using a monthly dataset of US stock prices for the period 1974-1978. This period signifies the change in exchange rate system in the US from fixed to floating. His research found that US Dollar was positively correlated with US stock prices during this period; a decrease in US Dollar resulted in



a decline in stock prices. Similar relationship between exchange rates and stock prices was found by Abdalla and Murinde (1997) using bivariate vector autoregressive model on monthly observations from 1985-1994. These empirical studies assert a causal relationship where exchange rates lead stock prices.

Conversely, stock price movements can also influence the movements in exchange rates. The second school of thought proposed by Branson et al. (1977), known as the portfolio balance approach, hypothesizes a causal relationship arising from stock prices leading to exchange rates. This approach believes that exchange rates are determined by market mechanisms thus causing capital account transactions influencing exchange rate dynamics. It argues that a country attracts foreign capital flows when its stock market is flourishing that is, stock prices increase and domestic currency will appreciate. It establishes a causal relationship from the stock prices to exchange rates. Hatemi-J and Irandoust (2002) demonstrate this causal relationship for Sweden using Toda-Yamamoto Granger non-causality test for the period 1993 to 1998. A recent study by Tsagkanos and Siriopoulos (2013) uses structural nonparametric cointegrating regression model to study the relationship between stock prices and exchange rates. They also find a causal relationship from stock prices to exchange rates for European Union (EU) in the long-run and for US in the short-run. Chkili and Nguyen (2014) also find that stock prices have a strong effect on exchange rates in normal as well as in times of high volatility. Similar results are found by Kim (2003) Kim (2003) and Ibrahim and Aziz (2003) for the US and Malaysia, respectively.

From the above discussion we can see that there is theoretical and empirical support for causality between exchange rates and stock prices in either direction. Bahmani-Oskooee and Sohrabian (1992) were the first to find bidirectional causality between the two in the short-run, but they do not find such evidence in the long-run. Other studies such as, Ajayi and Mougoue (1996);

Caporale et al. (2014); Pan et al. (2007) have also found mixed results. Using a sample of eight advanced economies, Ajayi and Mougoue (1996) find negative causal relationship from stock prices to currency value in the short-run. But in the long-run, they find positive relationship in the same direction. Contrastingly, they also find a negative causal relationship from exchange rates to stock prices in the short- as well as long-run. Caporale et al. (2014) study the interdependence between stock prices and exchange rates for the US, the UK, Canada, Japan, the EU and Switzerland. They find unidirectional causal relationship from stock returns to exchange rates in the US and the UK whereas an opposite causal relationship for the case of Canada. Study presents evidence of a bidirectional relationship in the EU and Switzerland in the short-run during the banking crisis period from 2007 to 2010. Variance in linkages between stock prices and exchange rate is also found by Pan et al. (2007) for seven East Asian countries from 1988 to 1998. They find that a causal relationship exists from exchange rates to stock prices for Hong Kong, Japan, Malaysia and Thailand prior to the Asian financial crisis of 1997. But during the crisis period, they find causal relationship in the same direction for all countries except Malaysia. They also find causality in the opposite direction for Hong Kong, Korea and Singapore prior to the crisis but no causality during the crisis. Noman et al. (2012) also do not find any causality between foreign exchange market and stock market of Bangladesh during the stock market crash of 1996. But on the other hand, Lee-Lee and Hui-Boon (2007), who present detailed account of exchange rate volatility of Malaysian ringgit, Indonesian rupiah, Thai baht and Singapore dollar during the pre- and post-Asian crisis in 1997, find that stock markets have significant influence on exchange rates in all economies. Several other studies (Bartov and Bodnar, 1994; Bodnar and Gentry, 1993; Griffin and Stulz, 2001; Jorion, 1990, 1991; Ozair, 2006) have failed to find any significant interdependence between the movements of stock prices and exchange rates of US

companies. Griffin and Stulz (2001) also conclude that weekly changes in exchange rates have negligible impact on industry performance in the short-run.

Based on the review of current literature we conclude that though there is a clear theoretical explanation to the relationship between exchange rates and stock prices, empirical evidence is contradictory. Ramasamy and Yeung (2005) argue that the results are diverse due to the nature of interaction between exchange rates and country's stock prices, which is sensitive to uncertainties in market structures within an economy. Pan et al. (2007) suggests that linkages differ across countries with respect to exchange rate system, size of trade, the extent of control on capital, and size of the stock market. Research thus far has ignored the perspective of India. This study aims to test this relationship from the standpoint of Indian market. This paper will add to the body of existing knowledge by examining the dynamic linkage between Rupee-Dollar exchange rates and performance of Indian IT industry. Change in India's exchange rate system accompanied by the efforts of the Indian government to boost its IT industry by developing Special Economic Zones (SEZs) has made its IT sector export-dominant. Sizeable workforce, low cost of labour, fluency in English language and an export based growth industry have also added to industry's competitive advantage; see Crookes and McManus (2013). Previous literature focusing on this subject with respect to Indian IT sector is scant. Agrawal et al. (2010) evaluate the interdependence and causal relationship between stock market volatility and movements in Dollar-Rupee rates. Using a correlation model and Granger causality test, they identify that the two variables are negatively correlated, rising from stock prices leading to exchange rates during the period 2007-09.

Authors have also looked at the related issue of entrepreneurship in Asian markets and Indian markets, including expanding the scope of methodologies used in entrepreneurships research,

such as; Dana (2000, 2007), and Dana and Dana (2005). Another study by Prasad and Panduranga Reddy (2009) finds that during the global financial crisis of 2007-08, foreign institutional investors withdrew their investments fearing economic slowdown which resulted in sharp depreciation of the Rupee. Due to huge withdrawals, the Indian stock market suffered its biggest stock market crash, i.e. Sensex, fell below 10,000 points in October 2008 (Bombay Stock Exchange Ltd., 2008). Therefore to better understand the relationship between exchange rates and stock prices from an Indian perspective, this study will assess their dynamic relationship using AGDCC GARCH model, cointegration methodology and Granger non-causality test, which is discussed in the next section.

### **3. Methodology, data and preliminary statistics**

In this study, we employ various econometric techniques to identify the empirical relationship between exchange rates of Indian Rupee-US Dollar and stock prices of four major IT companies of India. To examine dynamic time-varying correlations we use AGDCC GARCH model and to estimate long-run equilibrium relationship we use Bivariate Cointegration methodology. Similarly, to identify the direction of causality between these variables we utilize Granger non-causality test. The following is the brief description of above mentioned empirical models.

#### *Identifying order of integration*

To identify the order of integration of Indian Rupee-US Dollar exchange rates and stock prices of IT companies we employ conventional unit root tests namely; Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and Phillips-Perron (PP) test (Phillips and Perron, 1988). These unit root tests are employed to examine whether given data series is stationary or non-stationary at levels. Both ADF and PP tests have similar hypothesis that is; the null hypothesis of unit root (non-stationary) is tested against the alternative hypothesis of no unit root (stationary).

### Estimation of time-varying correlations

We are interested in examining how the correlations are changing over time between Indian Rupee-US Dollar exchange rates and stock prices of IT companies. For this purpose, we utilize a modified version of dynamic conditional correlation (DCC) GARCH model i.e. AGDCC GARCH model. This AGDCC GARCH model is a better model as it incorporates asset-specific news and conditional asymmetries into the model for estimating correlations of two series. Another advantage of this model is that it captures the heterogeneity that presents in the data series. Engle (2002) was the first author to introduce a DCC model for measuring time-varying correlations between the two assets and it is described in the following equation:

$$Q_t = (1 - a - b)\bar{P} + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1} \quad (1)$$

$$P_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (2)$$

Where  $\bar{P} = E[\varepsilon_t \varepsilon'_t]$ ,  $a$  and  $b$  are scalars such that  $a + b < 1$ .  $Q_t^* = (q_{iii}^*) = \lfloor \sqrt{q_{iii}} \rfloor$  this is a diagonal matrix with the square root of the  $i$ th diagonal element of  $Q_t$  on its  $i$ th diagonal position. If  $Q_t$  holds as long as positive definite then  $Q_t^*$  is a matrix which ensures  $P_t = Q_t^{*-1} Q_t Q_t^{*-1}$  is a correlation matrix with ones on the diagonal and every other element  $\leq 1$  in absolute value. The above Eq. (1) and (2) do not allow for incorporating asset-specific news and asymmetries impact on measuring the correlations. We therefore follow the modified version of DCC model of Cappiello et al. (2006) which is explained in the following equation:

$$Q_t = (\bar{P} - A'\bar{P}A - B'\bar{P}B - G'\bar{N}G) + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + G'n_{t-1}n'_{t-1}G + B'Q_{t-1}B \quad (3)$$

In the above equation,  $A$ ,  $B$  and  $G$  represent for  $k \times k$  parameter matrices, and  $n_t = I[\varepsilon_t < 0] \circ \varepsilon_t$  ( $I[\cdot]$  is a  $k \times 1$  indicator function which takes the value of 1 if the argument is true and otherwise 0, while " $\circ$ " indicating Hadamard product),  $\bar{N} = E[n_t n'_t]$ . Thus, above Eq. (3) is the modified

version of DCC i.e. AGDCC model. The Eq. (3) can be further interpreted, If the matrices of  $A$ ,  $B$  and  $G$  are replaced by scalars, then asymmetric DCC model can be treated as a special case of AGDCC. In a similar way, if matrix  $G = 0$ , then generalized DCC is a special case of AGDCC. The expectations are infeasible for  $\bar{P}$  and  $\bar{N}$  are replaced with sample analogues,  $T^{-1} \sum_{t=1}^T \varepsilon_t \varepsilon_t'$  and  $T^{-1} \sum_{t=1}^T n_t n_t'$ , respectively.

*Investigation of long-run relationship*

The above estimated correlations will reveal how the dynamic relationship between the studied variables is changing over time. However, this will not convey whether these variables have long-run relationship or not. For this reason, we utilize VAR based cointegration methodology developed by Johansen (1988, 1991) the VAR model with order  $p$  can be written as follows:

$$z_t = c + A_1 z_{t-1} + \dots + A_p z_{t-p} + \mu_t \tag{4}$$

Where  $z_t$  is an  $n \times 1$  vector of variables that are integrated of order one i.e.  $I(1)$ , and  $\mu_t$  is a zero mean with white noise vector process. This VAR model can be re-written as follows:

$$\Delta z_t = c + \Pi z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-i} + \mu_t \tag{5}$$

Where  $\Pi = \sum_{i=1}^p A_i - I$  and  $\Gamma_i = - \sum_{j=i+1}^p A_j$ . If the coefficient matrix has reduced rank  $r < n$ , then

there exist  $n \times r$  matrices  $\alpha$  and  $\beta$  each with rank  $r$  such that  $\alpha\beta'$  and  $\beta'z_t$  is stationary.  $r$  is the number of cointegrating relationships, the elements of  $\alpha$  are known as the adjustment parameters in the vector error correction model and each column of  $\beta$  is a cointegrating vector. Johansen proposed two different likelihood ratio tests such as, trace ( $\lambda_{trace}$ ) and maximum eigenvalue ( $\lambda_{max}$ ) tests. These tests are estimating using the following equations:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^g \ln(1 - \hat{\lambda}_i) \quad (6)$$

$$\lambda_{max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (7)$$

Where  $T$  is the sample size,  $\hat{\lambda}_i$  and  $\hat{\lambda}_{r+1}$  are the estimated values of the characteristic roots obtained from the  $\Pi$  matrix. For trace test, the null hypothesis of  $r$  cointegrating vectors is tested against the alternative hypothesis of  $n$  cointegrating vectors. Similarly, for maximum eigenvalue tests, the null hypothesis of  $r$  cointegrating vectors is tested against the alternative hypothesis of  $r+1$  cointegrating vectors. We utilize MacKinnon et al. (1999) 5% critical values for the empirical results interpretation of this test.

#### *Identifying the direction of causality*

The above analysis will disclose the time-varying dynamic linkage and long-run equilibrium relationship between Indian Rupee-US Dollar exchange rates and IT sector performance. However, these results will not reveal the direction of causality between these variables. Therefore, to identify which variable causes which one, we employ Toda-Yamamoto version of Granger non-causality test. Toda and Yamamoto (1995) proposed an alternative procedure for testing causality in the framework of integrated and cointegrated variables. The advantage of this model is that it does not require the pre-testing of unit root tests and cointegration. This does not mean that it replaces the conventional hypothesis testing; rather it is a complementary method. This model uses a modified Wald (MWALD) test to examine restriction on the parameters of the VAR ( $k$ ) model, where  $k$  is the optimal lag length. To determine the optimal lag length for VAR ( $k$ ) we used Akaike Information Criterion (AIC) and also cross checked for residual serial correlations by using Autocorrelation Lagrange Multiplier (LM) test to make sure that the selected lag length does not have the problem of serial correlation. This approach has an

asymptotic chi-squared distribution with  $k$  degrees of freedom in the limit when a VAR  $[k + d(\max)]$  is estimated. Since these are standard econometric models so we have omitted detailed equations and assumptions of individual models for brevity. Broadly there are two steps involved in estimating this model. The first step is to find out the appropriate lag length in the VAR framework and determine the order of integration for  $d(\max)$ . Once the first step is completed then we can estimate VAR model by using levels data with a total of  $p = [k + d(\max)]$  lags. The second or final step is to apply the standard Wald criterion to the matrix of the first  $k$  VAR coefficients. Where,  $d(\max)$  is the maximal order of integration for the series in the system. For instance; there are two variables in the system and one variable is integrated of order I (1) and other one is order I (2). In such case, we consider  $d(\max)$  is 2; and if both variables are integrated with order I (1) then  $d(\max)$  is 1.

#### *Data*

This study utilizes daily closing prices data of four major IT companies that represent India's IT industry, namely, HCL, INFOSYS, TATA and WIPRO, and Indian Rupee-US Dollar exchange rates for the time period of 25 August 2004 to 05 September 2013. Data for closing prices and exchange rates are collected from Bombay Stock Exchange (BSE) and Reserve Bank of India (RBI), respectively. This data set has been utilized for achieving the study objectives.

#### *Preliminary statistics*

To understand the statistical properties of the data series we have applied descriptive statistics and results are presented in Table 1. Results show that HCL has the highest mean return (0.0005) and Wipro has a negative mean return (-0.0001). The maximum mean return is attained by HCL (0.1715) and followed by Infosys (0.1562), Wipro (0.1509), TATA (0.1427) and exchange rate (0.0402). The minimum mean return for all four IT companies and exchange rate is negative.



The highest standard deviation is found for TATA (0.0305) and HCL (0.0304) and the lowest is for exchange rate (0.0052). This indicates that TATA and HCL are the most volatile companies as compared to other companies that are considered in this study. All IT companies have negative skewness except exchange rate. This suggests that the return distribution of IT companies have long right tails and return series distribution of exchange rate has long left tail. The kurtosis values are found to be higher than the normal which suggests that the return distributions are relatively steeper than the normal distribution. The Jarque-Bera test rejects the null hypothesis of a normal distribution for four IT companies and exchange rate at 5 % significance level. This suggests that the return series are not normally distributed.

**[Insert Table 1 Here]**

#### *Unit root tests results*

In this study we use conventional unit root tests for level and first-order difference on stock prices of four major IT companies representing the Indian IT sector and exchange rate between US Dollar and Indian Rupee using ADF and PP tests. ADF and PP tests check the stationarity (no unit root) and non-stationarity (unit root) for the underlying series. In both the tests, the null hypothesis of unit root is tested against the alternative hypothesis of no unit root. The results of these tests are presented in Table 2. Results indicate that the null hypothesis of unit root is not rejected for exchange rates and stock prices at levels. However, when these tests are applied on the first-order difference then the null hypothesis of unit root is rejected at 5 % significance levels. Thus, at first-order difference all data series are stationary. This therefore indicates that all the variables have same order of integration i.e.  $I(1)$ . It is a precondition of the cointegration test that the order of integration should be the same.

**[Insert Table 2 Here]**

#### **4. Empirical results**

This section aims to provide information on the dynamic linkage between the exchange rates of Indian Rupee-US Dollar and Indian IT companies' performance. We have applied AGDCC GARCH model to estimate time-varying conditional correlations and long-run relationship between these variables is explored using bivariate cointegration methodology. Further, we applied Granger non-causality test to identify the direction of causality among the studied variables. The empirical results of these models are presented below.

##### *Unconditional and conditional correlations*

To estimate correlations between exchange rates and stock prices of four IT companies, we applied both unconditional and conditional models. The results of unconditional correlations are presented in Table 3. The unconditional correlations are calculated using log return series. Results display that exchange rates are negatively correlated with stock prices of all the four IT companies. Results indicate that as the exchange rate increases then stock prices of these IT companies decrease and vice versa. This implies that there is a negative relationship between the performance of IT companies and exchange rates in India.

**[Insert Table 3 Here]**

The time-varying dynamic conditional correlations between the exchange rates and stock prices of IT companies are presented in Figure 1. Results show that the highest correlation (0.14) between exchange rate and HCL is found on 16 March 2007 and the lowest correlation (-0.48) was observed on 12 October 2006. In case of Infosys, the highest correlation (0.33) was identified on 14 July 2008 and lowest (-0.25) was on 07 September 2004. Similarly, higher correlation (0.095) between the exchange rate and TATA was observed on 25 April 2012 and lowest correlation (-0.24) was witnessed on 24 January 2008. The highest correlation (0.18) for

exchange rate and Wipro is found on 25 April 2012 and lowest correlation (-0.41) was witnessed on 10 April 2013. On average, the highest negative correlations between the exchange rates and Infosys are observed. These time-varying conditional correlations suggest that the Indian Rupee-US Dollar exchange rates and stock prices of four IT companies are largely negatively correlated over time. This indicates that as the exchange rate increases (or value of Rupee depreciates) against the US Dollar, then the performance of IT companies significantly decreases. Thus, we can conclude that the Indian IT companies perform better when the Indian Rupee appreciates (or exchange rate falls) against the US Dollar.

**[Insert Figure 1 Here]**

#### *Johansen cointegration test results*

The unit root (ADF and PP) tests results suggest that all the underlying series have the same order of integration i.e.  $I(1)$ . This therefore indicates that there may be a cointegration relationship between exchange rates and stock prices of IT companies. To explore long-run equilibrium relationship between these variables we apply VAR based cointegration methodology developed by Johansen (1988, 1991). This methodology requires an estimation of VAR (p). In order to select an appropriate lag length we use Akaike Information Criterion (AIC) and Schwarz Criterion (SC). To identify the validity of lag length selected by AIC and SC we employ residual test of Autocorrelation LM test to check serial correlation among the residuals of lags. The test results suggest that AIC selects more appropriate lag length than that of SC, so we have selected a suitable lag length for this study based on AIC. The empirical results of bivariate cointegration test are presented in Table 4. Results display that there is no long-run relationship between the exchange rates and three IT companies that is, HCL, Infosys and TATA. However, we found that there is a long-run equilibrium relationship between

exchange rates and stock prices of Wipro. These results therefore suggest that only Wipro and exchange rates are reaching an equilibrium point and also shares a common trend in the long-run.

**[Insert Table 4 Here]**

#### *Toda-Yamamoto Granger non-causality test results*

The cointegration methodology results reveal only about the long-run relationship among the observed variables. In order to explore the direction of causality between the exchange rates and stock prices of four Indian IT companies, we employ Toda and Yamamoto (1995) procedure. This procedure also requires an optimal lag length which is selected on the basis of AIC criteria and it is cross checked for serial correlation among the residuals of lags using a standard autocorrelation LM test. Once we have identified suitable lag length we estimate a system of VAR models for a level data series.

The Toda-Yamamoto Granger non-causality test is now applied on pairwise variables that is, exchange rates and stock prices of each IT company. The causality results of modified Wald test is obtained from a VAR framework. The Granger non-causality test results are displayed in Table 5. Results show unidirectional causality that runs from stock prices of HCL, Infosys, TATA and Wipro to exchange rates. This indicates that all four IT companies Granger cause exchange rates in our study. Results also suggest that there is no evidence of reverse causality from exchange rates to IT companies. Based on these results, we can infer that the performance of Indian IT companies drive the value of Indian Rupee against the US Dollar.

**[Insert Table 5 Here]**

## **5. Conclusion**

This study aims to investigate the dynamic linkage between the Indian Rupee-US Dollar exchange rates and stock prices of four Indian IT companies, which represents for majority of the

IT sector in India namely, HCL, Infosys, TATA and Wipro. Particularly, the study employs AGDCC GARCH model to estimate time-varying correlations and undertakes a cointegration methodology to explore a long-run equilibrium relationship among the observed variables. The study also uses Granger non-causality test to identify the direction of causality between the studied variables. To achieve these objectives study utilizes daily data of closing stock prices of IT companies and exchange rates from 25 August 2004 to 05 September 2013. Empirical results of AGDCC GARCH model show that there is a negative relationship between exchange rates and stock prices of IT companies and are time-varying over time. This indicates that as the exchange rate increases (the value of Rupee falls) against the US Dollar, then the IT companies perform poorly. In other words, Indian IT companies perform better when exchange rate falls (the value of Rupee appreciates) against the US Dollar.

The cointegration test results reveal that there is a long-run equilibrium relationship only between exchange rates and stock prices of Wipro. This indicates that there is no significant long-run equilibrium relationship among these variables. Further, Granger non-causality test results show that the null hypothesis of IT companies does not Granger cause exchange rates is strongly rejected at 5% significance level. This suggests that exchange rates do not drive the performance of four Indian IT companies. We infer that there is a negative association between exchange rates and the performance of IT companies. In other words, there is a positive relationship between the value of Rupee and Indian IT companies' performance. Previous studies (Branson et al., 1977; Hatemi-J and Irandoust, 2002; Tsagkanos and Siriopoulos, 2013; Chkili and Nguyen, 2014) also document a causal relationship from stock prices to exchange rates. This relationship is explained by the portfolio balance approach which gives importance to capital

account transactions and suggests that there is an increased flow of foreign capital when stock prices are increasing thus causing the exchange rates to appreciate.

These results have an important policy and practical implications. Policy makers can foresee the movements in exchange rates and accordingly adjust their exposure to foreign transactions. The results of this study also have important implications for the investment society. Since it is common to include currency as an asset in the investment portfolio, thus understanding the relationship between exchange rates and stock prices may equip portfolio managers to handle risk efficiently. Findings of this study may also useful for other IT growing emerging economies to understand the link between exchange rates and the performance of IT firms. However, manner of relationship between them may vary from country to country as the performance of other economic fundamentals can influence. To the best of authors' knowledge this is the first study to investigate the dynamic linkages between the Indian Rupee-US Dollar exchange rates and stock prices of Indian IT companies using various robust econometric methodologies. In this context, this is also the first study to apply AGDCC GARCH model to measure the time-varying conditional correlations between these variables. Therefore, our study has significant contribution to the body of knowledge on the linkage between exchange rates and stock prices.

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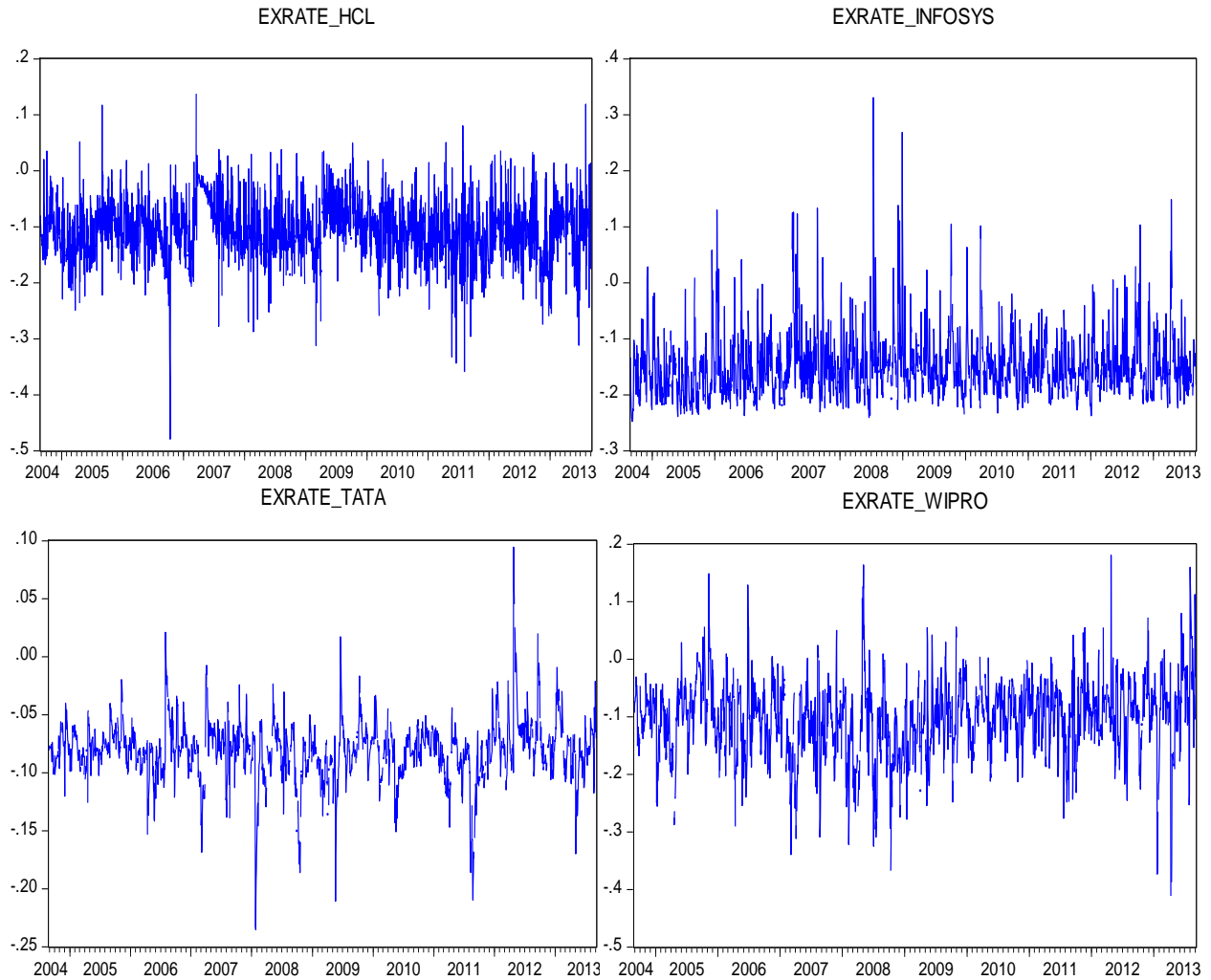
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Figure 1: Correlations of Indian rupee value (against US \$) and IT companies performance



**Table 1.** Descriptive statistics

Variables	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Exchange Rate	0.0002	0.0402	-0.0301	0.0052	0.3439	7.8033	2145.5430**
HCL	0.0005	0.1715	-0.7087	0.0304	-5.6502	139.6097	1712230.0000**
Infosys	0.0003	0.1562	-0.7008	0.0256	-9.5057	260.9663	6096996.0000**
TATA	0.0003	0.1427	-0.7130	0.0305	-11.1446	261.0433	6112953.0000**
Wipro	-0.0001	0.1509	-0.6841	0.0294	-7.9647	174.2254	2694738.0000**

Note: where ‘\*\*’ indicates rejection of null hypothesis of normal distribution at 5% significance level.

**Table 2.** Unit root test results

Variables	ADF Test				PP Test			
	Level		First Difference		Level		First Difference	
	With Trend				With Trend			
	T-Test	Prob.	T-Test	Prob.	Adj. T-Test	Prob.	Adj. T-Test	Prob.
Exchange rate	-0.5621	0.9806	-45.7980	0.0000**	-0.6827	0.9734	-45.8331	0.0000**
HCL	-1.1669	0.9158	-45.6851	0.0000**	-1.0616	0.9336	-45.7241	0.0000**
Infosys	-2.5975	0.2815	-47.8976	0.0000**	-2.5386	0.3092	-47.8981	0.0000**
TATA	-1.6318	0.7803	-46.2661	0.0000**	-1.4312	0.8518	-46.4999	0.0000**
Wipro	-2.8502	0.1794	-48.0236	0.0000**	-2.7512	0.2160	-48.0784	0.0000**

Note: Both unit root tests are carried out on with constant and tend variables in the model. Where ‘\*\*’ indicates rejection of null hypothesis of unit root (non-stationary) at 5% significant level.

**Table 3.** Unconditional correlations

Variables	Exchange rates	HCL	Infosys	TATA	Wipro
Exchange rates	1	-0.0832	-0.0946	-0.0592	-0.0938
HCL		1	0.3577	0.3244	0.3625
Infosys			1	0.3961	0.4227
TATA				1	0.3847
Wipro					1

**Table 4.** Bivariate cointegration test results

Variables	Null Hypothesis	Trace Statistic	Critical Value (5%)	Prob.	Max-Eigen Statistic	Critical Value (5%)	Prob.
Exchange Rate and HCL	$r = 0$	8.5367	15.4947	0.4099	6.9036	14.2646	0.5006
	$r \leq 1$	1.6330	3.8415	0.2013	1.6330	3.8415	0.2013
Exchange Rate and Infosys	$r = 0$	9.4460	15.4947	0.3257	8.2055	14.2646	0.3582
	$r \leq 1$	1.2406	3.8415	0.2654	1.2406	3.8415	0.2654
Exchange Rate and TATA	$r = 0$	6.9707	15.4947	0.5811	4.7856	14.2646	0.7686
	$r \leq 1$	2.1851	3.8415	0.1393	2.1851	3.8415	0.1393
Exchange Rate and Wipro	$r = 0$	15.5105	15.4947	0.0497**	15.4513	14.2646	0.0323**
	$r \leq 1$	0.0592	3.8415	0.8077	0.0592	3.8415	0.8077

Note: where ‘\*\*’ indicates rejection of null hypothesis of no cointegrating vector at 5% significance level.

**Table 5.** Toda-Yamamoto Granger non-causality test results

Null Hypothesis	Chi-sq	Prob.	Lag Length
HCL does not Granger cause Exchange rate	36.3453	0.0000**	7
Exchange rate does not Granger cause HCL	10.7984	0.1477	7
Infosys does not Granger cause Exchange rate	12.5678	0.0278**	5
Exchange rate does not Granger cause Infosys	4.5001	0.4799	5
TATA does not Granger cause Exchange rate	16.1213	0.0065**	5
Exchange rate does not Granger cause TATA	2.4407	0.7854	5
Wipro does not Granger cause Exchange rate	9.2843	0.0257**	3
Exchange rate does not Granger cause Wipro	2.0454	0.5630	3

Note: '\*\*' indicates rejection of null of hypothesis of no causality at 5 % significance level.