# Multi Scale Analysis of Stock Prices, Interest Rate and Exchange Rates: A Study of India

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**Abstract**
This study analyses dynamic linkage between stock price, exchange rate and interest rate for India using maximum overlap discrete wavelet transform (MODWT) which is very much appropriate when the variables are in discrete in nature. We use monthly data on stock return, exchange rate and interest rate from January 2000 to December 2014. Our major findings indicate that the empirical relationship between these variables is not significant at lower scales. As we go on higher scales, there is a linkage between them and three markets are associated with each other. Moreover, the direction and type of the relationship depends on the frequency bands and finally with the help of Granger causality tests we established a lead/lag relationship between stock price, exchange rate and interest rate.

**Keywords:** Exchange Rate, Stock Price, Interest Rate, modified overlap discrete wavelet transform (MODWT), India
**JEL Codes:** C22, E44, G15

## 1. Introduction

The post-liberalization era in India particularly since 2000 has increased the interdependence between key financial markets. There are ample of studies in the literature, which examine pair-wise dynamic linkage between exchange rates and stock prices, stock prices and interest rates, and exchange rates and interest rates for both developed and developing countries; see for example, Abdalla and Murinde (1997), Ajayi et al. (1998), Granger et al. (2000), Smyth and Nandha (2003) Phylaktis and Ravazzolo (2005), Moore (2007), Walid et al. (2011), Tsai (2012), Lin (2012), Hacker et al. (2012) and Moore and Wang (2014). The results are mixed because of diverse assumptions in the theoretical models and plethora of techniques in empirical analysis. The examination of co-movements between exchange rate, interest rate and stock prices are important from economic policies perspective as each financial market react quickly to the changes of economic fundamentals. Further, examining the dynamic relationship between stock market, foreign exchange market and capital market in case of emerging countries like India is more relevant because negative or positive shocks affecting one market may be transmitted quickly to another through contagious effect. Besides, it would be interesting to verify whether or not transmissions between the foreign exchange market, the equity market, and capital markets behave differently during crisis periods.

Fundamentally the dynamic linkage between stock prices and exchange rates is based on three main theoretical approaches. First, the flow-oriented approach by Dornbusch and Fischer (1980). According to them the flow-oriented models of exchange rates focus on the trade balance or current account balance. The proponents of these models state that changes in exchange rates affect international competitiveness and thus influence real output. Furthermore, because stock price can be interpreted as the present value of future cash flows of firms or industries, hence, it reacts to exchange rate changes.  Second, the stock-oriented approach by Frankel (1983) and Branson (1983), postulate that decrease in stock prices affect aggregate demand through wealth and liquidity effects, which in turn leads to a lower demand for money with ensuing lower interest rates. The low interest rates always discourage capital inflows of domestic country, which causes in depreciation of home currency against the foreign currency. Thus, through stock-oriented approach, exchange rate may be affected by stock price movements. Third, based on Mundell (1963) - Fleming (1962) model, an increase in interest rate is necessary to stabilize the exchange rate depreciation and to curb the inflationary pressure. The high interest rate policy raises the attractiveness of domestic financial assets as a result of which capital inflow takes place and thereby limiting the exchange rate depreciation. The higher interest rates also reduce the net value of future returns from the assets and hence reduce the stock prices.

A series of empirical papers focused on the relationship between stock returns and exchange rate using both cross-country and country-specific data. Some studies have indicated there are long-term equilibrium relation between stock price index and exchange rate (see: Smith, 1992; Abdall and Murinde, 1997; Granger et al., 2000; Ibrahim and Aziz, 2003; Kim, 2003; Patnaik et al., 2011; Katechos, 2011; Inci and Lee, 2014). Other studies have stated that the relationship between exchange rate and stock price is exists in short-run (see: Bahmani-Oskooee and Sohrabian, 1992; Nieh and Lee, 2001; Smyth and Nandha, 2003). Some propose that stock price and exchange rate are positively related (See: Phylaktis and Ravazzolo, 2005; Sevuktekin and Nargelecekenler, 2007; Diamandis and Drakos, 2011; Sensoy and Cihat, 2014).

Another strand of the literature examines the relationship between the interest rates and exchange rates (see: Baxter, 1994; Chinn and Meredith, 2004; Bautista, 2006; Choi and Park, 2008; Hacker et al., 2012). Exchange rates and interest rates are connected by the uncovered interest rate parity (UIP): Risk-neutral investors will be indifferent among the available interest rates in two countries since the exchange rate between these two countries is expected to adjust resulting in an elimination of a potential interest rate arbitrage. An exchange rate determination model in the flexible-price monetary tradition indicates a positive relationship between the interest rate differential and the exchange rate (Hacker et al., 2012). Chinn and Meredith (2004) found a positive relationship between interest rates and exchange rates was observable when using long-maturity data but the opposite occurred when using short maturity data for G7 countries. Similarly, Choi and Park (2008) evaluated the causal relationship between interest rates and exchange rates during the Asian crisis period.

There are few studies that examined the dynamic relationship between stock market and foreign exchange market in the context of India. Mishra (2004) using Granger's Causality test and Vector Auto Regression technique on monthly stock return, exchange rate and interest rate found a unidirectional causality between the exchange rate and interest rate, but no Granger's causality between the exchange rate return and stock return. Narayan (2009) apply several variants of the EGARCH model to examine the role of depreciation of the Indian rupee on India's stock market. The results found that volatility persistence has been high and appreciation of Indian rupee over the 2002 to 2006 has generated more stock returns and less volatility. Andries et al. (2014) investigate the co-movement of interest rate, stock price and exchange rate in India in the period between July 1997 and December 2010 using the cross-wavelet power, the cross-wavelet coherency, and the phase difference methodologies. They found that there exists co-movement among these three variables and relationship depends on the frequency bands.

Based on these ambiguity results between exchange rates, stock prices and interest rates, which have found from the existing review literature, this paper makes an attempt to examine the dynamic linkage among these three variables in India using the Wavelets analysis. Our paper differs from the existing literature in three ways. First, though bulk of studies in India examined pair-wise relationship among these three variables using standard VAR, Cointegration, Granger causality approachs, there is hardly any study except (Andries et al., 2014), which check the relationship in the presence of frequency domains. Second, Andries et al. (2014) use the continuous wavelet analysis using monthly data. But our paper uses maximum overlap discrete wavelet transform (MODWT) which is very much appropriate when the variables are in discrete in nature. We use monthly data on stock price, exchange rate and interest rate which are discrete in nature and hence motivate us to see whether the findings from our study are similar or divergent to Andries et al. (2014). Third, our study uses data of more recent years i.e. till December 2014 as compared to Andries et al. (2014) which used data till December 2010. Though the global financial crisis started in 2008, but the failure of decoupling hypothesis was actually noticed in India after 2010, particularly from 2011 to 2013. Therefore, an examination of the dynamic relationship between three markets in India is very much crucial particularly beyond 2010. Our major findings indicate that the empirical relationship between these variables is not significant at lower scales. As we go on higher scales, there is a clear linkage between them and three markets are associated with each other. Moreover, the direction and type of the relationship depends on the frequency bands and finally with the help of Granger causality tests we established a lead/lag relationship between stock price, exchange rate and interest rate.

The rest of the paper is organized as follows. Section 2 explains the detailed methodology of the maximum overlap discrete wavelet transform (MODWT) and data sources. Section 3 presents the empirical results and the last section is the conclusion. Conclusions are found in Section 4.

## 2. Methodology

Wavelets have the ability to decompose any time series into several sub-series which are associated with particular time scale. Processes at these different time-scales, which otherwise could not be distinguished, can be separated using wavelet methods and then subsequently analysed with ordinary time series methods. Gençay et al. (2002) argue that wavelet methods provide insight into the dynamics of economic/financial time series beyond that of standard time series methodologies. Financial time series are most complex in nature. However, we can consider some facts like stock price, exchange rates, and interest rates indices are discontinuous in nature and stationarity does not easily hold. Wavelets work naturally in the area of non-stationary time series, unlike Fourier methods which are crippled by the necessity of stationarity. In recent years the interest for wavelet methods has increased in economics and finance. This recent interest has focused on multiple research areas like exploratory analysis, density estimation, analysis of local in homogeneities, time scale decomposition of relationships and forecasting (Crowley, 2007). This is possible because of the capability of wavelets to decompose on different time scales yet still preserve the time localization.

Gençay et al. (2001) investigate the scaling properties of foreign exchange rates using wavelet methods. They use the maximal overlap discrete wavelet transform estimator of the wavelet variance to decompose variance of the process and find that foreign exchange rate volatilities are described by different scaling laws on different horizons. Similar wavelet multi scale studies are also analysed by Gençay et al. (2001, 2003, 2005), Gençay & Selçuk(2004), and Gençay & Fan (2009). The maximal overlap discrete wavelet transform (MODWT) is one, which is a modification of the ordinary discrete wavelet transform (Percival and Walden, 2000). This transform loses orthogonality but acquires attributes suitable for economic research like smoothness and possibility to analyse non-dyadic processes (processes that are not multiples of two). Kim and In (2005, 2006, 2007) have conducted many studies in finance using the wavelet variance, wavelet correlation and cross-correlation. Kim and In (2005) study the relationship between stock markets and inflation using the MODWT estimator of the wavelet correlation. They conclude that there is a positive relationship between stock returns and inflation on a scale of one month and on a scale of 128 months, and a negative relationship between these scales.

### *2.1. Modified Overlap Discrete Wavelet Transform*

A wavelet is essentially a small wave which grows and decays in a limited time period. There are two main classes of wavelets: the continuous wavelet transforms (CWT) and its discrete counterpart (DWT).As noted by Percival and Walden (2000), the majority of the wavelet analysis applications in the economic field concentrate exclusively on the DWT because it is a more natural way of handling discrete time series such as those commonly used in economics and finance. The Maximal

Overlap Discrete Wavelet Transform (MODWT) is similar to the Discrete Wavelet Transform (DWT) in that high pass and low-pass filters are applied to the input signal at each level. However, in the MODWT, the output signal is not subsampled (not decimated). Instead, the filters are up sampled at each level. As pointed by Gallegati (2012), the wavelet coefficients can be straightforwardly manipulated to achieve several recognizable statistical quantities such as wavelet variance, wavelet correlation, and wavelet cross-correlation. The wavelet variance decomposes the variance of a time series on a scale by-scale basis and constitutes a useful tool for determining what time scales are the dominant contributors to the overall variability of a series (Percival and Walden, 2000).

Let $X_t$ be a stationary stochastic process with variance $\sigma_X^2$. If $\sigma_X^2(\lambda_j)$ denotes the wavelet variance at scale $\lambda_j$, then the following relationship holds:

$$\sigma_X^2 \; = \sum_{j=1}^{\infty} \sigma_X^2(\lambda_j) \tag{1}$$

where $\sigma_X^2(\lambda_j)$ represents the contribution of the changes at scale $\lambda_j$ to the total variance of the process. This relationship states that the wavelet variance provides an exact decomposition of the variance of a time series into components associated to different time scales.

An estimator for wavelet correlation is constructed using the MODWT. This estimator was introduced by Percival (1995), Whitcher (1998) and Whitcher et al. (2000). An estimator for wavelet cross-correlation is a natural extension of the estimator of wavelet correlation and has similar properties. The MODWT coefficients indicate changes on a particular scale. Thus, applying the MODWT to a stochastic time series produces a scale-by-scale decomposition. The basic idea of wavelet variance is to substitute the notion of variability over certain scales for the global measure of variability estimated by sample variance (Percival and Walden 2000). Same applies to wavelet covariance. The wavelet covariance decomposes sample covariance into different time scales. In other words, wavelet covariance on a particular time scale indicates the contribution of covariance between two stochastic variables from that scale. The wavelet covariance at scale $\lambda_j \equiv 2^{j-1}$ can be expressed as (Gençay et al. 2002)

$$cov_{xy}(\lambda_j) = \frac{1}{\breve{N}} \sum_{t=L_j-1}^{N-1} d_{j,t}^{X} d_{j,t}^{Y}$$

(2)

where $d_{j,t}^{I}$ are the MODWT wavelet coefficients of variables l on a scale $\lambda_j$. $\breve{N}_j$ = N - $L_j$ + 1 is the number of coefficients unaffected by the boundary, and $L_j$ = ($2^j$-1)(L-1) + 1 is the length of the scale $\lambda_j$ wavelet filter. An estimator of the wavelet covariance can be constructed by simply including the MODWT wavelet coefficients affected by the boundary and renormalizing. This covariance is, however, to some degree biased. Because covariance is dependent on the magnitude of the variation of time series, it is natural to introduce the concept of wavelet correlation. The wavelet correlation is simply made up of the wavelet covariance for $\{X_t, Y_t\}$ and the wavelet variance for $\{X_t\}$ and $\{Y_t\}$.The MODWT estimator of the wavelet correlation can be expressed as

$$\rho_{XY}(\lambda_j) = \frac{cov_{xy}(\lambda_j)}{\sqrt{V_X(\lambda_j) V_Y(\lambda_j)}} \qquad (3)$$

where

$$V_l(\lambda_j) = \frac{1}{\breve{N}} \sum_{t=L_j-1}^{N-1} [d_{j,t}^{X}]^2 \qquad (4)$$

I = X, Y is the wavelet variance of stochastic process (Percival, 1995).

### *2.2. Granger Causality Analysis*

Finally, the Granger causality analysis (GCA) is used to investigate whether one time series can correctly cause another (Granger, 1969).

If we have two time series *X* and *Y*, the paired model is as following:

$$Y_t = \sum_{n=1}^{p} A_n X_{(t-p)} + \sum_{n=1}^{p} B_n Y_{(t-p)} + CZ_t + E_t \qquad (7)$$

$$X_t = \sum_{n=1}^{p} A_n^{'} Y_{(t-p)}^{'} + \sum_{n=1}^{p} B_n^{'} X_{(t-p)}^{'} + C^{'} Z_t + E_t^{'} \qquad (8)$$

$X_t$ and $Y_t$ represent the two time series at time *t*. $X_{(t-p)}$ and $Y_{(t-p)}$ represent the time series at time *t-p, p* representing the number of lagged time points (order). $A_n$ and $A_n^{'}$ are signed path coefficients. $B_n$ and $B_n^{'}$ are auto regression coefficients and $E_t$ and $E_t^{'}$ are residual.

### *2.3. Data*

This paper uses monthly data on Real Effective Exchange Rate, monthly average closing prices of NSE S&P CNX index and call money rate of the Reserve Bank of India as interest rate over the period January 2000 to December 2014. All the variables are collected from Handbook of Statistics on Indian Economy published by RBI and CEIC database published by Euro money Institutional Investor Company. We considered the stock prices in the return form while both the interest rates and exchange rates are in their level form.

## 3. Results and Discussion

We presented the descriptive statistics of all three variables in Table 1. In terms of standard deviations, the volatility of stock market is higher than that of exchange market, so the investment risk of stock market is higher than exchange market.

**Table 1: Descriptive statistics**

| | Interest Rate | Stock Returns | Exchange Rates |
|---|---|---|---|
| Mean | 6.94 | 0.92 | 103.60 |
| Median | 6.64 | 1.96 | 102.14 |
| Maximum | 54.32 | 18.14 | 115.87 |
| Minimum | 0.17 | -27.03 | 96.67 |
| Std. Dev. | 4.32 | 6.17 | 4.81 |
| Skewness | 7.56 | -0.75 | 0.74 |
| Kurtosis | 82.33 | 5.08 | 2.41 |
| Jarque-Bera | 48641.96*** | 48.7*** | 19.11*** |

*** indicates 1% level of significance.

The mean monthly return over the study period is positive for stock returns implying an increasing trend. The measure of skewness and kurtosis indicate that both interest rate and exchange rate are positively skewed, whereas, the stock return is negatively skewed. Similarly, we also notice that interest rate series is highly leptokurtic and exchange rate is platykurtic with respect to normal distribution. The Jarque-Bera statistic rejects the normality for each of the series at 1% level. Before doing any analysis, it is important to test the stationary property of a variable. We apply both Augmented Dicky Fuller (ADF) and Phillips and Perron (PP) unit root tests and we find that interest rate and stock returns are stationary at level, whereas, the exchange rate series are non-stationary at level but stationary at first differenced form[1].

[1] We have not presented the results of ADF and PP unit root tests to save space, however, it can be obtained from the author upon request.

**Figure 1(a): Plot of call money rate**

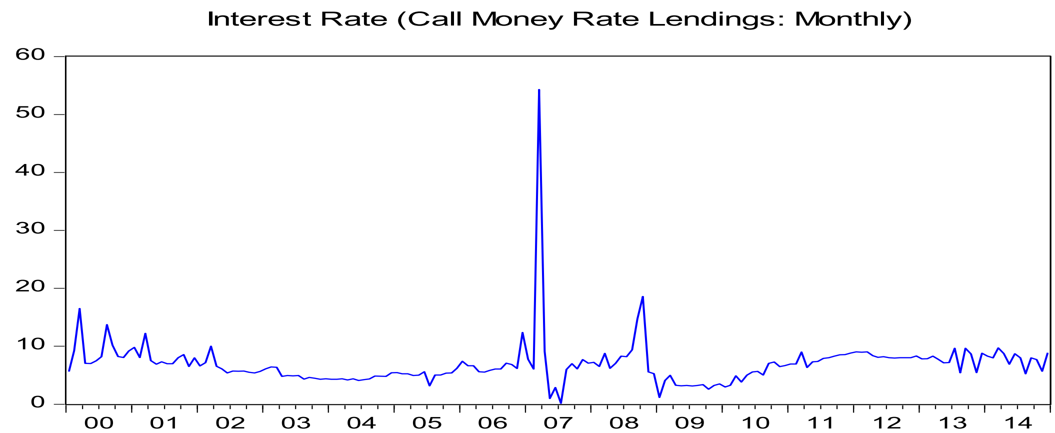



**Figure 1(b): Plot of stock returns**

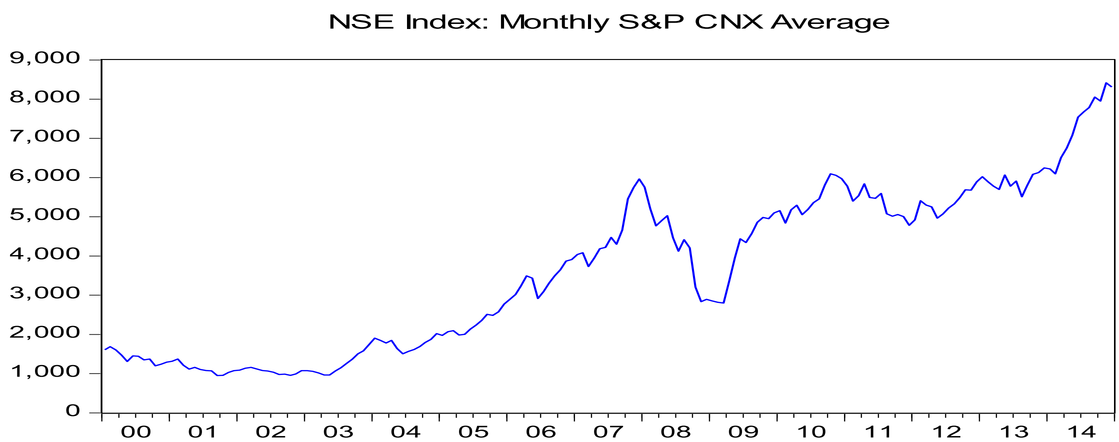
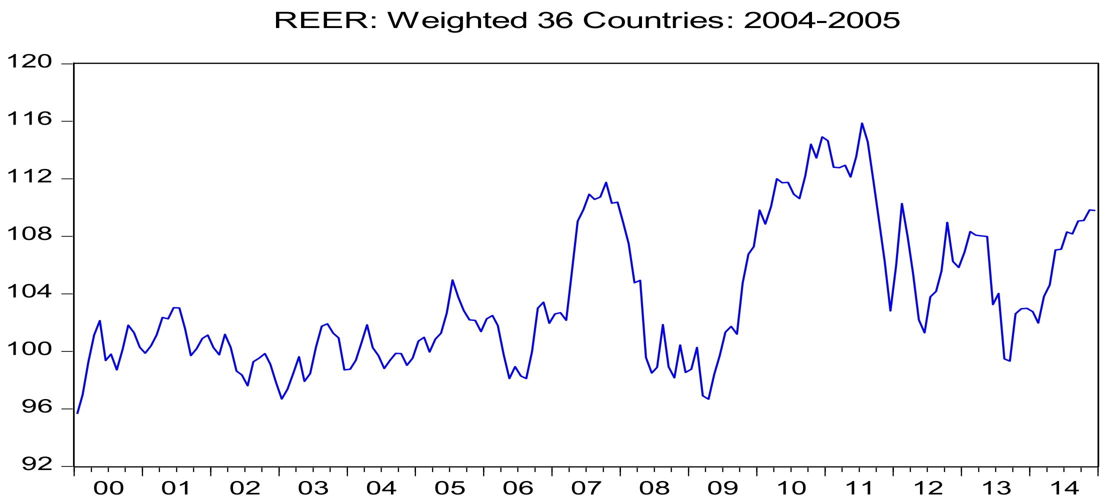
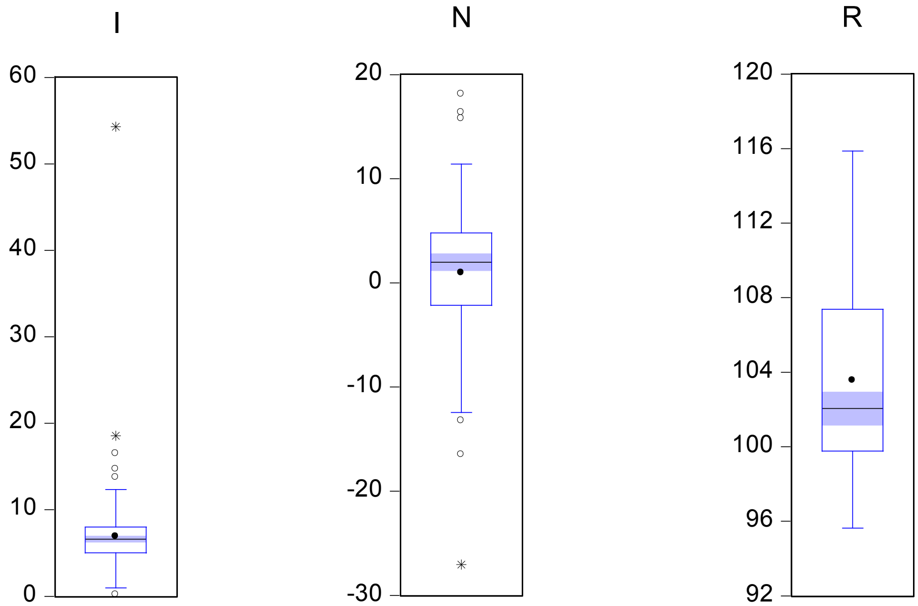



**Figure 1(c): Plot of real effective exchnage rate**




The plots of Figure 1(a) – (c) indicate the movement of all the three series over the periods. In our study, we preferred monthly data over weekly or daily data for a number of reasons. Firstly, monthly data contain less noise and can therefore better capture the interactions between interest rates and stock prices. Secondly, monthly data have smaller biases due to nonsynchronous trading of some individual stocks. Thirdly, the results in terms of smoothness and distinction among the different time horizons produced by wavelet analysis on monthly data are much harder to achieve with higher frequency data. Consequently, to find similar results to those obtained with monthly data, a very large number of decomposition levels are required when using weekly or daily data.

**Figure 2: Plots of series data of Interest Rate, Stock Prices and Exchange rates**




We examine the dynamic linkage between interest rate, stock prices and exchange rate through wavelet analysis. We apply the maximal overlap discrete wavelet transform to the monthly returns for the three series using the Daubechies (*D*) wavelet filter of length *L* = 4, that is D(4), based on four non-zero coefficients Daubechies (1992), with periodic boundary conditions. Since monthly data are used, the scale 1 represents the highest frequency and is associated with a time horizon of 2 to 4 months. In turn, scales 2 to 7 correspond to 4-8, 8-16, 16-32, 32-64, 64-128 and 128-256 monthly periods, respectively. So, overall we have performed the analysis which is useful for both short-term and long-term investors.

**Figure 3: Wavelet variance plots of interest rate, stock prices and exchange rate**

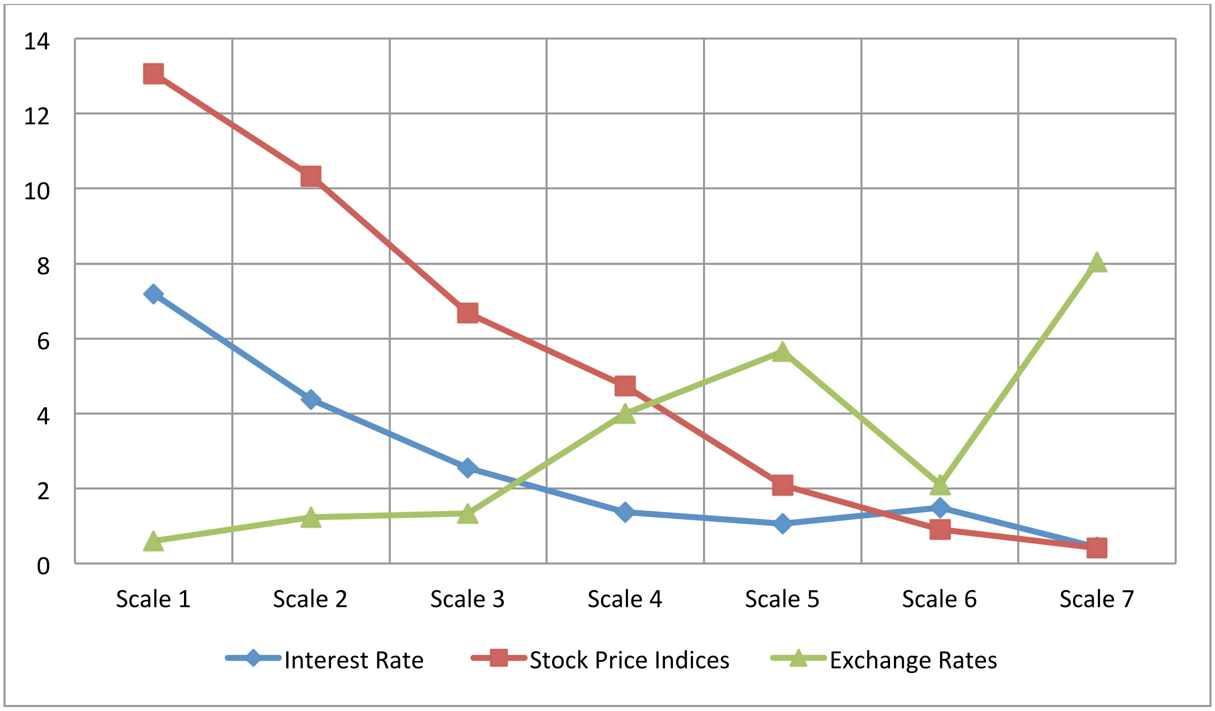
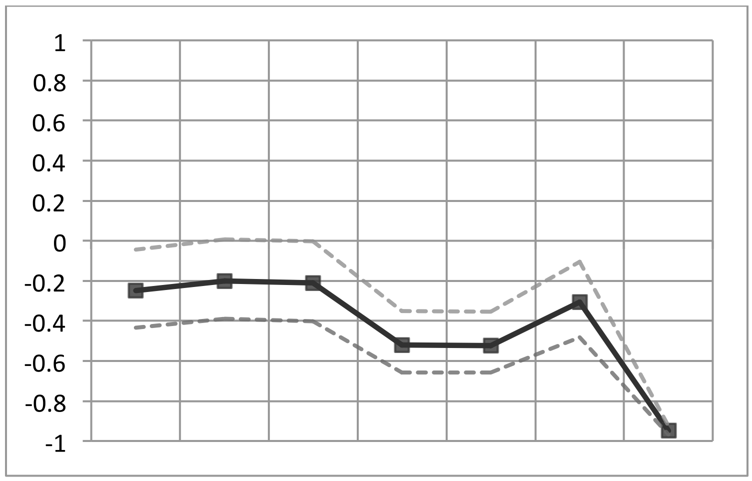


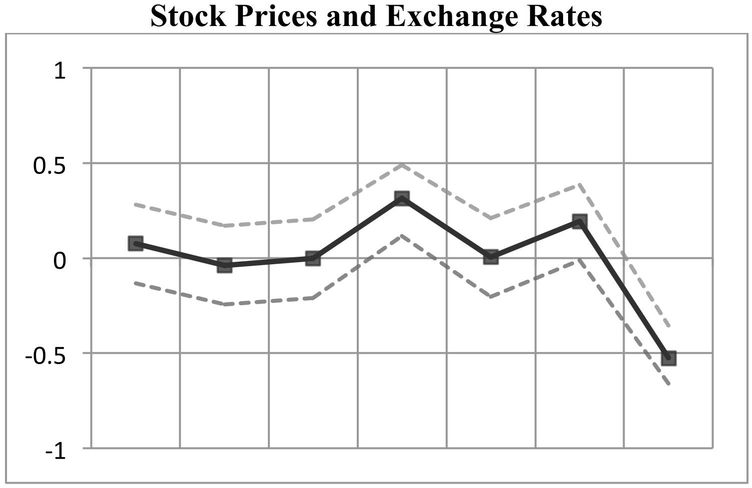

Fig. 3 illustrates the Wavelet variance of the three variables over time scales up to scale 7 for the whole sample. Two things are noteworthy from this figure. First, there is an approximate linear relationship with negative slope between the wavelet variance and the scale in case of interest rate and stock prices, suggesting that the wavelet variances of these two variables decline as the wavelet scale increases. This greater stability in the long run seems to indicate that investors with short-term horizons face higher risks than investors with longer investment horizons. Second, the Wavelet variances of stock returns are higher than those of call money rates over all time scales except the initial. Our finding is consistent with that of Kim and In (2007) for the G7 countries, confirming that the stock market are more volatile than the public debt market regardless of the investment horizon. We can also observe that the wavelet variance of exchange rate is not consistent over time scales. It had an increasing trend with a sudden fall at level 6.

**Figure 4: Wavelet Correlation plots between the series of Interest rate, Stock Prices
and Exchange rates**

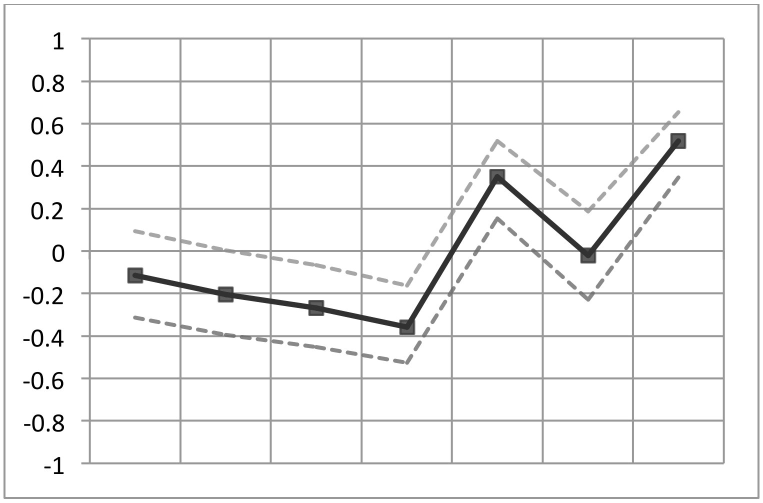
**Interest Rates and Stock Prices**




**Stock Prices and Exchange Rates**




**Exchange Rates and Interest Rates**




In our study, we have evaluated wavelet correlation between the pair-wise variables to estimate the relation between them at different scales. All these results have been presented graphically in the Figure 4. In the plots, the dashed lines indicate the 95% confidence intervals of the corresponding wavelet correlation, which are represented by solid black line with values emphasized by square boxes at different scales. The signs of wavelet correlation in case of Interest rate and stock prices are negative in all the scales, implying stock prices are hampered with the increase of Interest rates. This is in accordance to the prior research of several countries and also consistent with known fact of inverse relationship between Interest rates and stock prices.

In the case of stock prices and exchange rates, the wavelet correlation is not significantly different from zero almost at all the scales and there seems to be not much effect on one another. While in the case of exchange rates and interest rates, we can observe a Wavelet correlation bearing a negative value and also taking a decreasing trend at lower scales indicating inverse relationship, while the same inverse relation isn't observed at the higher scales. One of the main purposes of this paper is to establish lead/lag relationship between the three variables interest rates, stock prices and exchange rates over various time scales using the wavelet analysis. For this purpose we have plotted the cross-correlation curves for the three variables at different scales (Figure 5, 6 and 7) and also tested them for Granger Causality, presented in the Table 2 below. As we can observe from Table 2 that the pair-wise causality do exists among all the three variables mostly at higher scales (D4, D5, D6 and D7). The results indicate a bi-directional Granger causality between stock price and interest rate at higher scales, but found no causality at lower scales. While examining the causality between real exchange rate and interest rate, this study found a unidirectional causal relationship from interest rate to exchange rate, but the reverse is not true. Finally, we also notice a bi-directional causality between real exchange rate and stock prices at higher scales.

**Table 2: Multi scale Granger causality analysis**

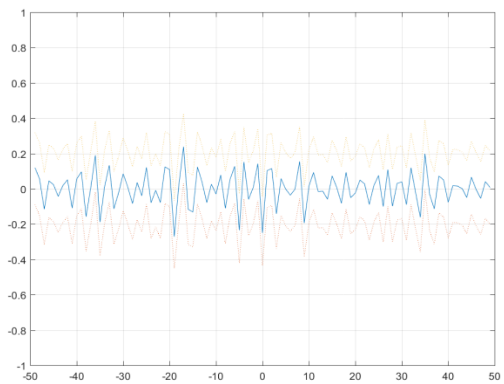
| | S | D1 | D2 | D3 | D4 | D5 | D6 | D7 |
|---|---|---|---|---|---|---|---|---|
| SP -> IR | 0.212<br>(0.808) | 0.568<br>(0.567) | 0.724<br>(0.486) | 1.704<br>(0.185) | 5.015***<br>(0.008) | 2.345*<br>(0.099) | 16.43***<br>(0.00) | 14.36***<br>(0.000) |
| IR -> SP | 1.275<br>(0.282) | 0.500<br>(0.607) | 0.897<br>(0.410) | 4.019**<br>(0.020) | 3.806**<br>(0.024) | 4.363**<br>(0.014) | 4.20**<br>(0.016) | 16.24***<br>(0.000) |
| FX -> IR | 0.881<br>(0.416) | 0.590<br>(0.555) | 0.143<br>(0.866) | 0.610<br>(0.544) | 1.654<br>(0.194) | 2.317<br>(0.102) | 1.08<br>(0.342) | 3.76**<br>(0.025) |
| IR -> FX | 2.39*<br>(0.094) | 0.712<br>(0.492) | 0.190<br>(0.826) | 0.753<br>(0.472) | 6.730***<br>(0.002) | 48.37***<br>(0.00) | 4.95***<br>(0.008) | 11.27***<br>(0.000) |
| FX-> SP | 0.114<br>(0.892) | 0.267<br>(0.766) | 2.634*<br>(0.075) | 2.040<br>(0.133) | 7.548***<br>(0.001) | 2.202<br>(0.114) | 0.998<br>(0.370) | 8.13***<br>(0.000) |
| SP-> FX | 0.766<br>(0.466) | 0.608<br>(0.545) | 0.044<br>(0.956) | 1.214<br>(0.299) | 2.316<br>(0.102) | 2.916*<br>(0.057) | 4.75***<br>(0.010) | 36.10***<br>(0.000) |

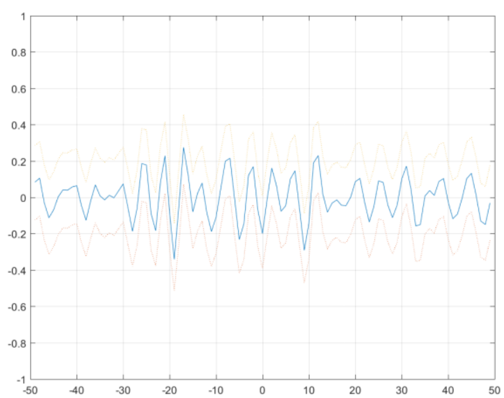
***, **, * indicate 1%, 5%, and 10% level of significance, respectively.

After discussing the multiscale causality among stock price, exchange rate and interest rate, this study further presents the Wavelet cross-correlation plots between interest rate, stock price and exchange rate at time t-λ and t+λ up to 50 month lags, with the corresponding approximate confidence intervals, against time leads and lags for all scales.

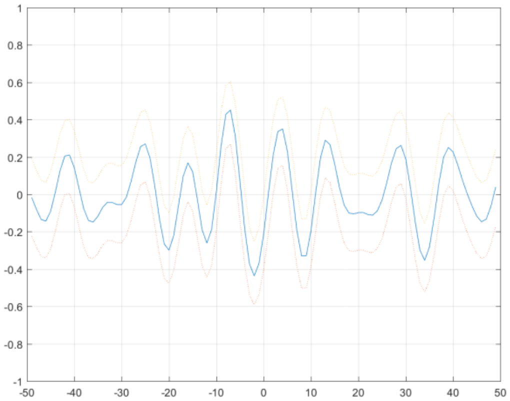
**Figure 5: Wavelet cross-correlation plots between interest rate and stock price**

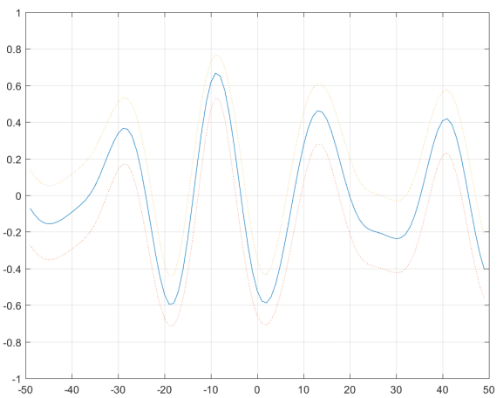
**Level 1** **Level 2**



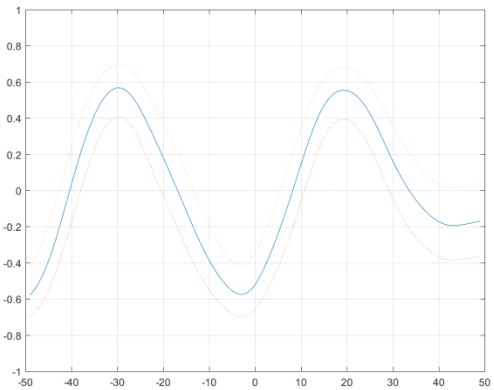



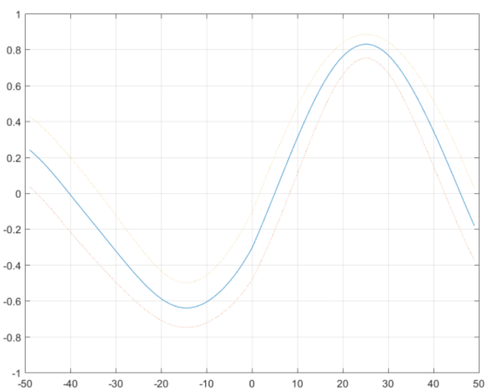

**Level 3** **Level 4**





**Level 5** **Level 6**





**Level 7**

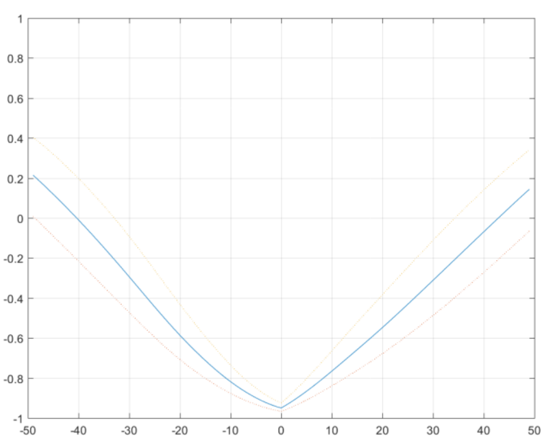
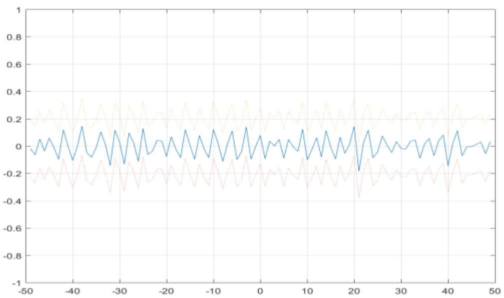
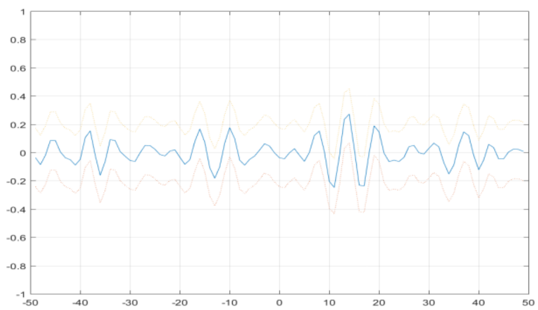


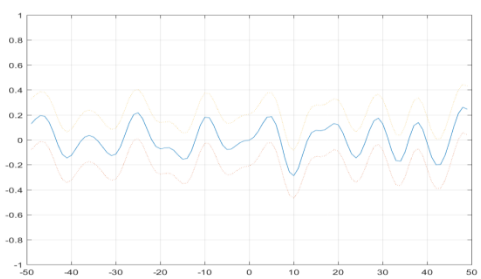
**Figure 6: Wavelet cross-correlation plots between stock price and exchange rate**

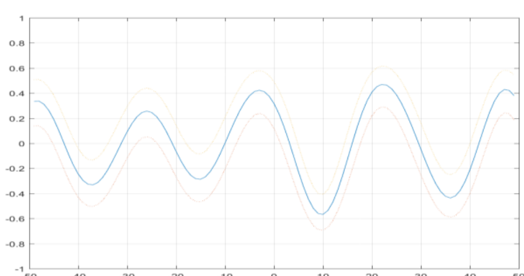
**Level 1** **Level 2**



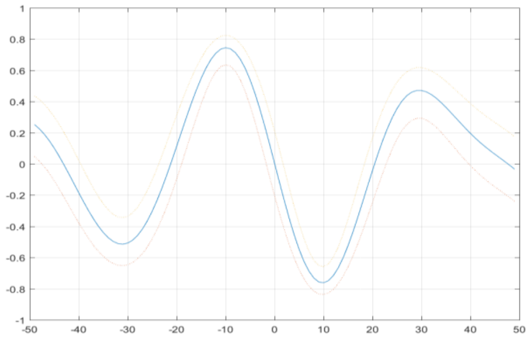



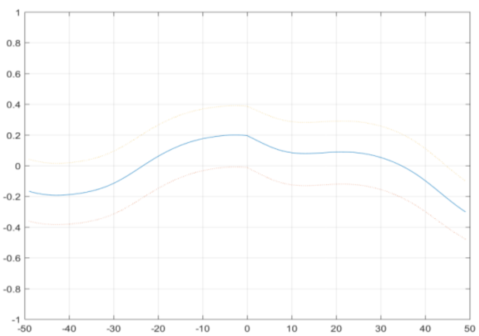

**Level 3** **Level 4**




**Level 5** **Level 6**




**Level 7**

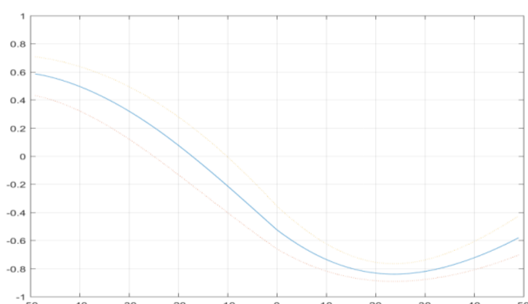
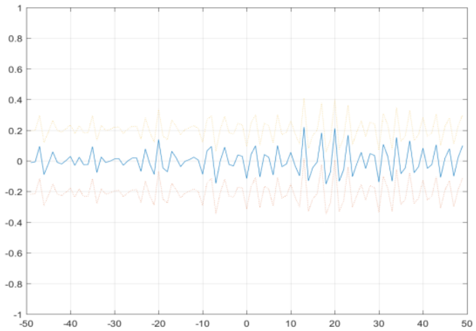
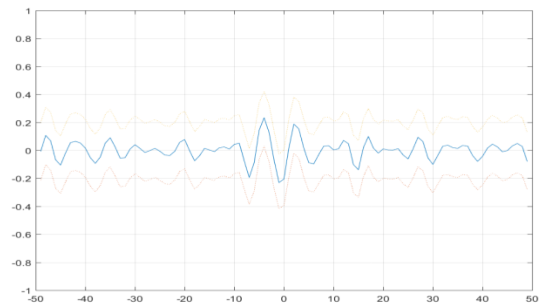


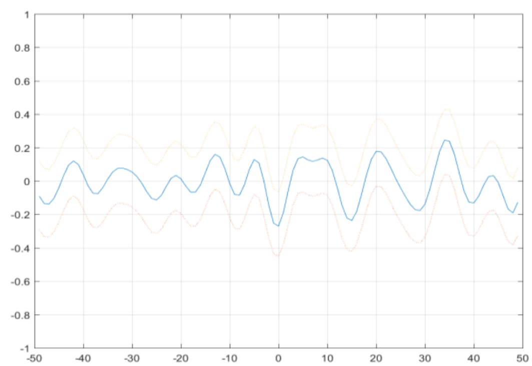

**Figure 7: Wavelet cross-correlation plots between exchange rate and interest rate**

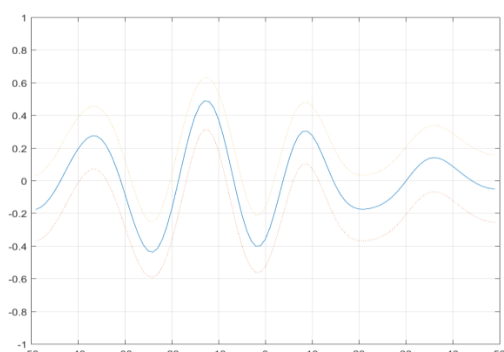
**Level 1** **Level 2**



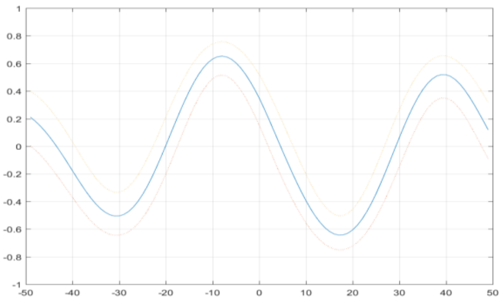



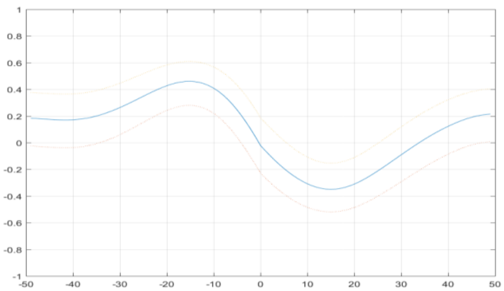

**Level 3** **Level 4**



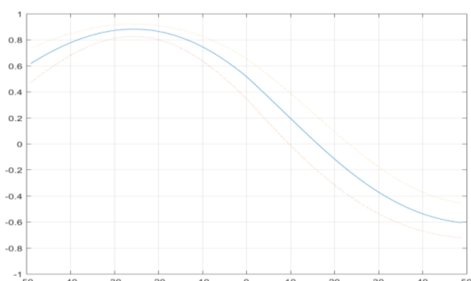




**Level 5** **Level 6**





**Level 7**



The figures 5-7 illustrate the Wavelet cross-correlation results, which indicate that the values of all the relations are not significantly different from zero at lower scales at both leads and lags. According to Fig-5, the dynamic Wavelet cross-correlation between interest rate and stock prices are negative at higher scales, which validate the theory. The theory states that an increase in the interest rates would put pressure on the company's ability to arrange more funds by issuing stocks and it reduces the profit, which in turn reduce the stock returns. Similarly, we also notice a negative Wavelet cross correlation between stock price and exchange rate for the higher scales. This result is not surprising. The increase in stock returns attracts more Foreign Institutional Investors (FIIs) to invest in the Indian stock market. The rises in stock return increase the demand for Indian rupees in the foreign exchange market, and hence, appreciation of Indian rupee against foreign currencies put downward pressure on REER. Finally, we noticed a positive relationship between interest rate and exchange rate, especially in the lags. The reason lies behind the fact that in many emerging markets with infamous history of crowding out effect because of budget deficits, which plays an important role in investment. If the interest rates increase for any reason, it is generally perceived as an upcoming problem in the country thus increase the real exchange rate.

### 4. Conclusions

There is abundant literature which examines the pair-wise linkage between stock price, exchange rate and interest rate by using plethora of techniques. The aim of this paper was to investigate dynamic linkage between these three variables for India using maximum overlap discrete wavelet transform (MODWT) which is very much appropriate when the variables are in discrete in nature. We use monthly data on stock return, exchange rate and interest rate from January 2000 to December 2014. Our major findings indicate that the empirical relationship between these variables is not significant at lower scales. As we go on higher scales, there is a clear linkage between them and three markets are associated with each other. Moreover, the direction and type of the relationship depends on the frequency bands and finally with the help of Granger causality tests we established a lead/lag relationship between stock price, exchange rate and interest rate. Our results further revealed a negative relationship between interest rate and stock price in higher scales, which is opposite to the findings of Andries et al. (2014).

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