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A Bivariate Linear and Nonlinear Causality between Stock Prices and Exchange Rates

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Abstract

The present study examines dynamic relation between stock index and exchange rate by using the daily data for India. The study uses the unit root and cointegration tests to test for the long run relationship between the two variables. The study also uses linear and nonlinear granger causality tests after removing the volatility dependence from the series to examine the dynamic relationship between the two variables. Following Hristu-Varsakelis and Kyrtsou (2008), the nonlinear granger causality between stock index and exchange rate is investigated by using bivariate noisy Mackey Glass model. The empirical evidence suggests that there is no long-run relationship; however, there is bidirectional linear and nonlinear granger causality between stock index and exchange rates. The findings of the study strongly support the micro and macroeconomic approach on the relationship between exchange rates and stock prices.

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1. Introduction

In the last two decades, globalization, interlinkages of the capital markets, gradual eradication of capital inflow barriers and the implementation of more flexible exchange rate mechanism in developed as well as transition economies, created a systematic interdependency between and within the stock and foreign exchange markets (Aydemir, O. and E. Demirhan, (2009)). Thus, investigating the relationship between stock prices and exchange rates has received unprecedented attention in the literature. The study by Bahmani-Oskooee and Sohrabian (1992), Abdalla and Murinde (1997), Granger *et al.* (2000), Pan *et al.* (2007) etc., have concluded that the two markets play an important role in the growth of a country and the relationship between exchange rates and stock prices are microeconomic as well as macroeconomic in nature and may be observed on the short- and long-run.

The microeconomic level stands suggest that exchange rates lead the stock prices (Dornbusch and Fischer (1980), Ma and Kao (1990), Ajayi and Mongoue (1996), Yau and Nieh (2006)). While the macroeconomic approach assumes that there is a negative relationship between stock prices and exchange rates, with causality running from the stock market to the foreign exchange market (Bahmani-Oskooee and Sohrabian (1992), Granger *et al.* (2000), Caporale *et al.,* (2002), Stavárek (2005), Pan *et al.,* (2007)).

The above theories suggest causal relations between stock prices and exchange rates. However, empirical evidence on a micro level provides mixed results. The findings of Jorion (1990, 91), Bodnar and Gentry (1993), Bartov and Bodnar (1994), Choi and Prasad (1995), He and Ng (1998), Griffin and Stulz's (2001) suggests that stock prices of are not influenced by changes in exchange rates.

However, empirical results of the study done by Glaum *et al.* (2000), Entorf and Jamin (2002), Kyimaz (2003) and Bartram (2004) contradicts the findings of earlier studies (Jorion (1990, 91), Griffin and Stulz's (2001) etc.,) and shows the significant relationship between the two variables.

The empirical evidence on a macro level suggests relatively stronger relationship between stocks price and exchange rate. However, the results of causality test seem to be mixed. Most of the studies (Ajayi *et al.* (1998), Nieh and Lee (2001), Phylaktis and Ravazzollo (2005), Vygodina (2006), Ai-Yee Ooi (2009)) suggest the unidirectional causality from stocks to exchange rates. Few studies (Doong *et al.* (2005), Pan *et al.* (2007), Aydemir and Demirhan (2009) etc.,) have reported bidirectional causality between the stock prices and exchange rates.

However, study using Indian data suggests that there is no association between the exchange rates and stock prices. Muhammad and Rasheed (2002) examined the exchange rates and stock price relationships for four south Asian countries. The empirical results reveal that there is a bi-directional long-run causality between these variables for only Bangladesh and Sri Lanka. However, there is no long or short term relationship between exchange rates and stock prices for Pakistan and India. In a similar study, Smyth and Nandha (2003) investigated the relationship

between exchange rates and stock prices for the same countries. The empirical results reveal unidirectional causality running from exchange rates to stock prices for only India and Sri Lanka.

Bhattacharya and Mukherjee (2003) investigated Indian markets using the data on stock prices and macroeconomic aggregates in the foreign sector including exchange rate concluded that there in no significant relationship between stock prices and exchange rates. In a recent study, Rahman and Uddin (2009) investigated the interactions between stock prices and exchange rates in three emerging countries of south Asia. The results of granger causality test shows there is no way causal relationship between stock prices and exchange rates in the countries.

The earlier empirical evidences on relationship between exchange rate and stock return are at best mixed. The reason for the differences of results among different economies might be because of the different degree of the capital mobility, trade volume and economic links among them. Another reason could be an omitted variable bias-for example interest rates may have an influence on stock and currency markets.

The key problems associated with the previous studies are as follows. Several recent studies (Granger *et al.* (2000), Phylaktis and Ravazzollo (2005), Vygodina (2006), Pan *et al.* (2007), Ai-Yee Ooi (2009) etc.) have investigated the dynamic relations between exchange rates and stock index. These studies have used traditional linear granger causality test to explicitly examine the relationship between stock prices and exchange rates. The traditional granger causality test has high power in uncovering the linear causal relation. However, their power against nonlinear causal relations can be low (Baek and Brock (1992), Hiemstra and Jones (1993)). Thus, the causal relationship between exchange rates and stock prices may be nonlinear which the traditional granger causality test might overlook.

Moreover, the study done using the Indian market (Rahman and Uddin (2009), Bhattacharya and Mukherjee (2003) and Muhammad and Rasheed (2002)) suggests that there is no relation at all between exchange rates and stock prices. As discussed previously, there are two explanations (micro and macro approach) which suggest the possible relationship between the two variables. However, no consensus has been made between the two approaches.

Given this notion, the present study overcomes the drawback identified in the earlier study by examining the dynamic relations between stock index and exchange rates using linear and nonlinear granger causality tests for Indian market. In addition, we also use unit root and cointegration tests to analyze the long run equilibrium relationship between the two variables. In this study we concentrate on the macro level issues and contribute to the literature in the following ways.

In this study, we use a three-step empirical framework for examining dynamic relationships between exchange rates and stock index. In first step, we tests for the unit root, heteroscedasticity and cointegration for the two series. Next, we investigate the short term linear and nonlinear dynamic linkages between exchange rates and stock index. In last step, we eradicate the heteroscedasticity effect from the two series and again perform the linear and nonlinear granger causality tests.

The most commonly used nonlinear granger causality test is based on the study of Back and Brock (1992). Hiemstra and Jones (1994) further modified it by filtering the linear dependence from the series and using the residuals term of the vector autoregression model to tests the nonlinear causality. Thus, this test does not use the initial stationary variable. The studies of Kyrtsou and Serletis, (2006) states that the financial time series are highly complex. Moreover, in the presence of such dynamics, linear filtering of data using VAR methodology before the application of the Hiemstra and Jones test of nonlinear granger causality can lead to serious distortions (Kyrtsou and Serletis (2005)). Thus, Hiemstra and Jones (1994) test may fail to detect the correct causal relationship. The important point that distinguishes this study from the existing literature is methodology adopted to investigate the dynamic relationship between variables of interest. The study examines the dynamic relationship between stock index and exchange rates using the nonlinear causality test with a special type of nonlinear structure known as bivariate noisy Mackey–Glass model of (Kyrtsou and Terraza (2003) and Kyrtsou and Labys (2006).

Moreover, in recent years, there is more interest and research on Indian market data due to the country's rapid growth and potential opportunities for investors. It is estimated that foreign investment in the Indian stock markets may cross $10 billion-mark by the end of September 2009. Parallel to this, many firms that comprises the stock index (S&P CNX Nifty Index of National Stock Exchange) have American Depository Receipts (ADR's) or General Depository Receipts (GDR's) which are traded on the NYSE, NASDAQ or on non-American exchanges. Over the years, Indian Rupee is gradually moving towards full convertibility. The two-way fungibility of ADRs/GDRs allowed by RBI has also possibly enhanced the linkages between the stock and foreign exchange markets in India. This background makes the study more interesting and worthy to investigate, whether the dynamic linkages between foreign exchange of Indian Rupee/USA Dollar (INR/USD) and stock market index in India exhibits different characteristics vis-à-vis developed market and other emerging markets.

We believe that the outcome of this study would offer some meaningful insights to the existing literature, policy makers as well to the practitioners. The remaining portion of the paper is organized as follows: Section 2 describes the data and methodologies used. Section 3 presents the empirical results. Section 4 summarizes the findings and brings out the implication of the study.

2. Data and Methodology

The data set comprises of daily closing price of S&P CNX Nifty Index and INR/USD exchange rates obtained from the National Stock Exchange and Reserve Bank of India websites. The series span the period from 4th January 1999 to 31st August 2009. The daily stock index and INR/USD returns are continuously compounded rate of return, computed as the first difference of the natural logarithm of the daily stock index and INR/USD exchange rate value.

The stationary status of series should be tested when investigating the relationship between exchange rate and stock market price. In order to test the unit roots i.e. stationarity in the S&P CNX Nifty Index and INR/USD exchange rates, the study employ augmented Dickey and Fuller (ADF) test and KPSS test. If the findings of ADF and KPSS test suggests that the series are

integrated of order one, Engle and Granger (1987) methodologies should be used to determine whether any cointegrating vector among variables exists or not.

2.1 Vector Autoregression Model and Causality Test:

The study uses Vector Autoregression (VAR) model to examine the presence of linear granger causality. The benefit of VAR models is that they account for linear inter-temporal dynamics between variables, without imposing *a priori* restrictions of a particular model.

A VAR model including S&P CNX Nifty stock index returns and INR/USD exchange rates can be expressed as:

$$\Delta \ln S_t = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta \ln S_{t-i} + \sum_{i=1}^{m} \chi_i \Delta \ln ER_{t-i} + \varepsilon_{ser} \tag{1}$$

and

$$\Delta \ln ER_t = \eta_0 + \sum_{i=1}^{m} \mu_i \Delta \ln S_{t-i} + \sum_{i=1}^{m} \pi_i \Delta \ln ER_{t-i} + \varepsilon_{ers} \tag{2}$$

If cointegration exists between Nifty index and INR/USD series, then the granger representation theorem states that there is a corresponding error correction model. The error correction model for the Nifty index and INR/USD series can be represented as:

$$\Delta \ln ER_t = \alpha_0 + \delta z_{t-1} + \sum_{i=1}^{m} \mu_i \Delta \ln S_{t-i} + \sum_{i=1}^{m} \chi_i \Delta \ln ER_{t-i} + \varepsilon_{ser} \tag{3}$$

where $Z = \ln S_t - \gamma_0 - \gamma_1 \ln ER_t$, are the residuals from the cointegration regression of the log levels and $\Delta \ln S_t$ and $\Delta \ln ER_t$ are the log first difference of Nifty Index and INR/USD exchange rates respectively (or simple exchange rate returns and Nifty index returns).

Within the context of this VAR/VECM model, linear granger causality restrictions can be defined as follows: If the null hypothesis that χ's jointly equal zero is rejected, it is argued that INR/USD exchange rate returns granger causes Nifty Index returns. Similarly, if the null hypothesis that μ's jointly equal zero is rejected, Nifty returns granger cause exchange rate returns. If both of the null hypotheses are rejected, bi-directional granger causality, or a feedback relation, is said to exist between variables. Different test statistics have been proposed to test for linear granger causality restrictions. To test for strict granger causality for pairs of ($\Delta \ln S_t$, $\Delta \ln ER_t$) in this linear framework, a Chi-Square statistics is used to determine whether lagged value of one time series has significant linear predictive power for current value of another series.

2.2 ***Nonlinear Granger Causality Test***

The main disadvantage of the linear approach to causality is that, it fails to detect the nonlinear relationship between the variables (Hiemstra and Jones (1993)). In addition to linear linkages, exchange rate and index returns could have nonlinear relationship also. The investigation of

nonlinear causal relationships between these financial variables is of paramount importance for having the better understanding of the true impact of shocks. Moreover, when non-linear causality is identified, there is a strong possibility that a small variation in one variable can have multiplicative and non-proportional effects on the others (Kyrtsou and Labys (2006)).

Hence, this study uses a nonlinear causality test known as the *bivariate noisy Mackey-Glass (M-G) model* (Kyrtsou and Terraza (2003), Kyrtsou and Labys (2006) to examine the complex dynamic relationship between stock index returns and INR/USD returns. The nonlinear causality model assumes an underlying process with a special type of non-linear structure. The general form of the model is as follows:

$$X_t = \alpha_{11}\frac{X_{t-\tau_1}}{1+X_{t-\tau_1}^{c_1}} - \delta_{11}X_{t-1} + \alpha_{12}\frac{Y_{t-\tau_2}}{1+Y_{t-\tau_2}^{c_2}} - \delta_{12}Y_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0,1) \quad (4)$$

$$Y_t = \alpha_{21}\frac{X_{t-\tau_1}}{1+X_{t-\tau_1}^{c_1}} - \delta_{21}X_{t-1} + \alpha_{22}\frac{Y_{t-\tau_2}}{1+Y_{t-\tau_2}^{c_2}} - \delta_{22}Y_{t-1} + \upsilon_t, \upsilon_t \sim N(0,1) \quad (5)$$

where α and δ are parameter to be estimated. τ is the delay parameter and c is a constant. The model requires prior selection of the parameters of the M-G process, namely τ_1, τ_2, c_1, c_2. The best delays τ_1, τ_2 are chosen on the basis of Schwarz criterion. The parameters of M-G model that best fits the given series, is estimated using ordinary least squares.

The nonlinear causality model examines whether past observation of a variable Y have a significant non-linear effect (of the type $\frac{Y_{t-\tau_2}}{1+Y_{t-\tau_2}^{c_2}}$) on the current value of another variable X and vice versa. Algorithmically, the test is similar to the linear granger causality test, except that the two models fitted to the series are M-G processes. The principle advantage over simple VAR alternatives is that the non-linear Mackey–Glass terms are able to filter more difficult dependent dynamics in a time series. The study uses the above bivariate noisy Mackey-Glass model for examining dynamic relationships between Nifty returns ($\Delta \ln S_t$) and INR/USD returns ($\Delta \ln ER_t$).

3. Results

3.1 Unit Root Test

The results of Augmented Dickey Fuller and KPSS for the two series namely Nifty Index and INR/USD is shown in Table 1.

Table 1: Unit Root Test

	ADF Test		**KPSS Test**	
Variable	**t-statistics**	**Critical Value**	**t-statistics**	**Critical Value**
$\ln S_t$ (Log level)	-0.6553	-3.4327	5.3562	0.739
$\Delta \ln S_t$ (First Diff)	-36.7465	-3.4327	0.0890	0.739
$\ln ER_t$ (Log Level)	-1.3609	-3.4327	0.7149	0.739

Δ lnER$_t$ (First Diff)	-52.5394	-3.4327	0.1765	0.739

The results of ADF and KPSS test suggests that the log level of Nifty index and exchange rates series are non stationary. However, for the log first difference for the two series i.e. Δ lnS$_t$ and Δ lnER$_t$ is stationary.

3.2 Engle and Granger Cointegration Test:

After testing for the unit root in the two series, we applied the two steps Engle and Granger cointegration tests on the log levels of the two series and tested its residuals for stationarity. The results of the cointegration regression are shown in Table 2.

Table 2: Engle and Granger Cointegration Test

Cointegrating Regression			
Coefficient	**Coefficient Value**	**t-statistic**	**Probability**
γ_o	25.3729	40.3541	0.0000
γ_1	-4.6699	-28.2934	0.0000
Unit Root Test of Cointegrating Errors			
ADF Test		**KPSS Test**	
t-statistics	**Critical Value (1%)**	**t-statistics**	**Critical Value (1%)**
-0.5415	-3.4327	5.4933	0.739

In order to determine of the variables are actually cointegrated, the cointegration error terms are tested for stationarity. The results of ADF and KPSS tests clearly indicate that the error terms are nonstationary. The results also indicate that there is no long run relationship between exchange rate and stock indices for India. Thus, an error correction term need not be included in the granger causality test equations. The findings of Engle and Granger Cointegration tests are consistent with the findings of previous studies for developed markets such as the USA, the UK and Japan (Bahmani-Oskooee and Sohrabian (1992), Nieh and Lee (2001), Phylaktis and Ravazzollo (2005) etc.) as well as for Asian market like India, Malaysia, Pakistan (Muhammad and Rasheed (2002), Rahman and Uddin (2009)). However, the results contradict the study of Abdallah and Murinde (1997).

4.3 Linear Granger Causality Test

In order to investigate the dynamic relationship (linear granger causality) between Nifty index returns and INR/USD returns, we use the bi-variate VAR model without the correction term as specified in equation 1 and 2. The Swartz Bayesian Information Criterion (SBIC) is adopted to determine the appropriate lag lengths for VAR models.

Panel A of Table 3 reports the linear causal relationship between Nifty index returns and INR/USD returns while the panel B reports the linear causality results between volatility filtered Nifty index and INR/USD returns.

Table 3: Linear Granger Causality Test

Panel A		
Null Hypothesis	Chi-Sq-Statistics	P-Value
Nifty Returns does not granger cause INR/USD	8.2422	0.0162**
INR/USD does not granger cause Nifty Returns	9.6352	0.0081*
Panel B (After Volatility Filtering)		
Null Hypothesis	Chi-Sq-Statistics	P-Value
Nifty Returns does not granger cause INR/USD	5.7282	0.0570***
INR/USD does not granger cause Nifty Returns	8.7882	0.0123*

* Represent the relationship being significant at 1 %
** Represent the relationship being significant at 5 %
*** Represent the relationship being significant at 10 %
The optimal lag length is 2 which are selected based on the SBIC criteria.

It is evident from the Panel A of Table 3 that the null hypothesis "Nifty Returns does not granger cause INR/USD" and "INR/USD does not granger cause Nifty Returns" is rejected. The Chi-Square statistics are significant and it provides the strong evidence for the argument that there is bidirectional linear granger causality between Nifty index and INR/USD returns.

We also investigated the dynamic relationship between the two variables after filtering out the volatility effects. Initially, we tested the two series for the ARCH effects. The result (available upon request) of the ARCH tests suggests that ARCH terms are present in both series. This suggests that there is need to re-examine the causality after removing the ARCH effects. Hence, we performed the linear granger causality tests using volatility filtered series of INR/USD and Nifty index returns. The results are presented in Panel B of Table 3. The causality tests again reveal that there is a bi-directional causality between the two variables.

4.4 Nonlinear Causal Relationship

This study use bivariate Mackey–Glass model (Kyrtsou and Labys (2003)) to detect nonlinear causality between index returns and exchange rate returns. The estimated results are reported in Table 4.

Table 4: Bivariate Noisy Mackey Glass Model

Panel A		
Null Hypothesis	F-Statistics	P-Value
Nifty Returns does not granger cause INR/USD	4.1211	0.01633**
INR/USD does not granger cause Nifty Returns	4.8176	0.0081*
Panel B		
Null Hypothesis	F-Statistics	P-Value
Nifty Returns does not granger cause INR/USD	0.8019	0.37065
INR/USD does not granger cause Nifty Returns	3.1067	0.078161***

* Represent the relationship being significant at 1 %
** Represent the relationship being significant at 5 %

*** Represent the relationship being significant at 10 %
The value of $\tau_1=1$, $\tau_2=1$, $c_1=2$, c2=1 is used based on the SBIC criteria in case of Panel A.
The value of $\tau_1=1$, $\tau_2=1$, $c_1=2$, c2=2 is used based on the SBIC criteria in case of Panel B.

From the Panel A of Table 4, it is evident that there is bidirectional nonlinear granger causality between index returns and the exchange rates returns. The F statistics are significant. Hence, the null hypothesis "Nifty Returns does not granger cause INR/USD" and "INR/USD does not granger cause Nifty Returns" is rejected.

In literature is has been stated that much of the nonlinear structure in daily stock prices is related to ARCH dependence, implying that the nonlinear test may only detect volatility dependence. Therefore, it may be useful and informative to apply bivariate M-G model of nonlinear causality tests to the volatility-filtered series (i.e., the series derived by removing the ARCH effect). Thus, the study also investigated the nonlinear dynamic relationship between the two variables after filtering out the volatility effects. The results are presented in Panel B of Table 4. The F-statistics are significant. Overall, from the results of the bivariate Mackey–Glass model, it can be concluded that there is a bidirectional nonlinear causality from index returns to exchange rate returns and from exchange rate returns to index returns.

The results contradicts the study of Muhammad and Rasheed (2002) and Rahman and Uddin (2009), who concludes that for the Indian market, there exists no causal relationship between stock prices and exchange rates. Moreover, the results are consistent with the findings of Doong *et al.* (2005) and Aydemir and Demirhan (2009). However, none of the above study has tested for the nonlinear causality between exchange rates and stock index.

The bivariate M-G model used in this study is powerful in detecting nonlinear causal dependence, but it provides no guidance in relation to the source of this dependence. In our view, the strong evidence of the existence of the nonlinear dynamic relationship between the stock index and exchange rates in India may be because of noise trading and speculative behavior of the investors. Moreover, in last one decade, the number of foreign institutional investors in India has increased. This resulted in the huge capital flows in the stock market of India. The capital flows in general are dependent on many issues such as risk, liquidity etc and are volatile in nature. Thus, net flow (inflow-outflow) might have induced nonlinearities in the variable. Moreover, India is moving steadily towards the full convertibility of its currencies. Thus, the government monetary policies may be other factors which would have induced nonlinearities in the variables of our interests.

5. Conclusion

In this study, an attempt has been made to examine the dynamic (causal) relationships between S&P CNX Nifty index returns and INR/USD exchange rate returns for the Indian market. Our study uses the ADF and KPSS tests to examine the unit root in the series and Engle and Granger test to check the long run relationship between the two variables. The outcome of cointegration tests is consistent with the findings of Muhammad and Rasheed (2002) and Rahman and Uddin (2009).

We also used the traditional linear granger causality tests and a bivariate Mackey–Glass model to examine the dynamic (linear and nonlinear causal) relationship between index returns and exchange rate returns. The evidence suggests the bidirectional linear and nonlinear causality from index returns to exchange rate returns and from exchange rate returns to index returns. The results presented in this study contradict the results obtained by Muhammad and Rasheed (2002) and Rahman and Uddin (2009).

In agreement with the Doong *et al.* (2005) and Aydemir and Demirhan (2009) the results provide evidence for the presence goods market approach and portfolio approach. The results are useful for regulators, market participants and academicians. The results imply the market inefficiency and lend support to the technical analysis. The market participants may consider the relationship between the exchange rate and stock index to predict the future movement of stock prices and exchange rate effectively. Moreover, the results can help the regulators to understand the structure of the market in a better way and then design the policy. In terms of policies relevance, the regulators in India should be very careful in conducting exchange rate policies or capital market polices as it may impact on the development of the financial markets.

Future research can be done by examining the cointegration between exchange rates and stock market index by including variables like US market data and interest rates. Moreover, the origin of nonlinearities in the variables can also be explored. Another interesting extension of this work would be to develop forecasting model using the information of the exchange rate and market index and tests the accuracy of such models.

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