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A study of interlinkage between foreign exchange and stock markets in India

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Abstract
This paper seeks to delve into the intricate connection between India's stock market and foreign exchange market. Employing Johansen cointegration test and Granger causality test, the study analyzes monthly data spanning from January 2000 to July 2022, focusing on exchange rate return (USD/INR), BSE SENSEX return, and NIFTY50 return. The findings unveil a sustained relationship between the two markets over the long term. Notably, the research highlights a one-way relationship between NIFTY50 return and exchange rate return, while no causal link is evident between BSE SENSEX and foreign exchange rate. The detection of a structural break in the series, as indicated by the Zivot-Andrews's test, underscores the dynamic nature of these markets. Despite variations in results across sub-sample periods, the confirmation of a long-term relationship between foreign exchange rate returns and stock market returns holds significance for investors, scholars, and policymakers alike.

Keywords: Exchange rate, Johansen cointegration, granger causality test, structural break

Introduction
In an increasingly complex scenario of the financial world, it is important for the researchers, policy makers, practitioners and market players to understand the dynamics and strategic interactions between stock and foreign exchange market. These two markets are the most sensitive segments of the financial system and are considered as the barometers of the country's economic growth. The introduction of floating exchange rate in 1973, reforms in financial market in early nineties and the Asian currency crisis of 1997-1998 have jointly made a strong pitch for the dynamic relationship between stock market and foreign exchange market. Any policy changes have direct ramifications in both of these sensitive markets.

The process of integration of Indian stock markets and foreign exchange market has been greatly influenced by the economic and financial sector reforms implemented since 1990s. Liberalization of investments related to FPI in Indian stock market has played a major role in the linkages of both markets. There are mainly two channels through which exchange rate and stock prices are related to each other, that is, the traditional channel and portfolio channel. The traditional channel (Dornbusch and Fisher, 1980) [5] is based on 'Goods Market' approach, which establishes the relationship between real exchange rate and level of economic activity. The appreciation/depreciation of real exchange rates affects international competitiveness of domestic goods and services, which impact the trade balance and real output of a country. Thus, the changes in real output impact current and future cash flows that finally causes stock price variation. Secondly, changes in exchange rate impact indebtedness of the corporates of the country. Appreciation of exchange rate results in reduction in the debt repayment obligation. So, the corporates have more money on hand to invest hence the stock price increases and vice-versa for depreciation of exchange rates. The portfolio channel approach (Frankel, 1983 Gavin, 1989) [6, 7], based on 'Asset Market' approach of exchange rate, establishes the impact of stock price variation on exchange rate. In an open economy aggregate demand driven increase in stock prices results in an increase in wealth as well as an increase in demand for money. Excess demand for money increases interest rate which in turn attracts foreign investment. Finally, increased foreign investment causes currency appreciation.

Similarly, a fall in stock price results in negative wealth effect and outflow of foreign investments, leading to currency depreciation. In this study, the major focus is on the interlinkage between exchange rate returns and stock market returns (NIFTY50, SENSEX) in Indian context.

The paper is organized as follows: the second section provides a review of literature on this topic and third section includes the methodology and objectives of the study. Fourth section deals with result and discussion without any structural breaks. Finally, the last section has the conclusion part. Again, the entire exercise is repeated with structural breaks.

Section 2: **Brief review of literature**

After the end of Bretton-Wood system in early 1973, many currencies started to float their currency against each other. The flexible exchange rate system came to force after that but India's move towards flexible rate came after the 1991 new economic policy. After the liberalization, privatization and globalization initiative the interlinkage between foreign exchange market and stock market of India was at the center of attention for the researchers and policy makers. There were many existing literatures on this interlinkage. We shall elaborate some prominent among them.

Apte (2001) [3] investigated the volatility of the stock market and foreign exchange market in Indian context by using EGARCH specification on daily data of USD/INR, BSE 30, NIFTY50 for the time period 1991-2000. The result showed volatility spillover from foreign exchange market towards stock market and not the reverse. Similarly, Sudarsana Sahoo et.al (2017) [18] investigated the price and volatility spillovers between Indian foreign exchange and stock markets over the sample period from April 4, 2005 to March 31, 2017 using BEKK-GARCH (1,1) model. They also divided the sample period into five sub-sample. They found unidirectional price spillover from stock market to forex market for full sample period. They found volatility spillover between them in two sub-sample period. Mishra (2004) examined whether stock market and foreign exchange markets were related to each other or not. He used Granger causality test and Vector Auto Regression technique on monthly stock return, exchange rate, interest rate and demand for money for the time period April 1992 to March 2002. He found there was a causal unidirectional relationship between exchange rate and interest rate and also between exchange rate return and demand for money and no relationship between exchange rate return and stock return. Agarwal et.al (2010) also analyzed the relationship between Nifty returns and Indian rupee-US Dollar exchange rates. They conducted their study from October 2007 to March 2009 on daily basis. They also found similar result like, unidirectional relationship between Nifty returns and Exchange rates. Deepti Gulati and Monika Kahani (2012) [8] also examined whether or not a causal relationship exists between foreign exchange rate and stock market in Indian context. They applied Granger causality and correlation test between USD/INR and Indian stock market indices (Nifty, Sensex) for the period of 2004 and 2012.But they found there was no relationship between them and correlation test result showed less positive relationship between them. Again Agrawal (2010) [1], Malarvizhi and Jaya (2012) [11], Nazaf and Najaf (2016) applied granger causality to investigate the relationship USD/INR exchange rate and Nifty returns and they got unidirectional relationship between exchange rate and Nifty returns. Similarly, Gulathi and Khakani (2012) applied Granger causality test to analyze causal relationship between foreign exchange rates and stock market and observed that there was no relationship between exchange rates and stock market in Indian context like Gulati and Kahani (2012) [8].

Qazi Zarrar Zia and Zahid Rahman (2011) [20] analyzed the dynamic relationship between stock market and forex market in terms Pakistan. They employed Engel-Granger cointegration test for long run relationship and Granger causality for short-run for the sample period Jan 1995 to Jan 2010 on monthly basis. They got the result that there was no long run relationship between stock market and exchange rates in long run and also there was no causal relationship between them. Zubair, Abdulrasheed (2013) [21] also used Johansen cointegration test for the possible cointegration and Granger causality to test causal relationship between stock market and monetary indicators (exchange rate and M2) before and during financial crisis for Nigeria. The result showed similar outcome that is, there is no cointegration between them both before and during financial crisis and unidirectional relationship between stock market and exchange rate and M2 existed before the crisis. Similarly, Zhang (2013) [19] applied Cointegration to study the relationship between real oil prices and real effective exchange rate US Dollar and the result showed that there was no cointegration existed between real oil price and real effective exchange rate. Javed Bin Kamal and A.K. Enamul Haque (2016) [9] studied the dependence pattern between stock market and forex market in South Asian countries mainly India, Bangladesh and Sri Lanka. They used daily data for the period July 31, 2009 to July 31,2013. They employed Copula-GARCH model and the outcome was that India and Bangladesh were more prominent investment destination in terms of risk-return criteria than Sri Lanka.

The above review of literature suggests that there is no consensus among the previous researchers on the existence of long run relationship between foreign exchange and stock market return. Secondly, the existing literature did not consider the possibility of structural break in the sample series. Against this backdrop there are two-fold objectives of the present paper.

1) To revisit the long-run relationship between foreign exchange and stock market return and to check whether any causal relationship exists or not between them.
2) To repeat the above analysis (1) with and without structural break and see whether any fundamental differences can be observed in the said relationship.

Section 3: Data source and methodology

The data on foreign exchange rate (USD/INR) are obtained from the websites of International Financial Statistics, IMF (International Monetary Fund). The data on Indian Stock market indices like, BSE SENSEX and NIFTY 50 are collected from the official web sites of National Stock Exchange and Bombay Stock Exchange. The time span of the data is from January 2000 to July 2022 for all the three variables. Here we have selected the Indian currency in terms of US dollar because US dollar is a globally accepted currency. So, to check the effectiveness of foreign exchange market, we need to focus on domestic currency rate (spot) against US dollar. Now the returns on exchange rate is calculated as follows:

Exchange rate return = $\ln (S_t/S_{t-1}) * 100$ where S_t = Spot exchange rate at time t and S_{t-1}= Spot exchange rate of the previous period (t-1). Similarly, we obtained the return series

of BSE SENSEX and NIFTY50.

Descriptive statistics can be useful for two purposes mainly: 1) to provide basic information about variables in a dataset and 2) to highlight potential relationship between variables. Descriptive statistics mainly includes Mean, Standard deviation (σ), Skewness (S), Kurtosis (K) and Jarque-Bera statistics.

We have calculated the coefficients of Skewness and Kurtosis to check whether the variables are skewed and leptokurtic or not. For normality check of the variables, we used Jarque-Bera test Statistic, i.e.,

$$JB= N-k/6[S^2+1/4(K-3)^2] \quad (1)$$

Where S for Skewness coefficient, K for Kurtosis coefficient, N is number of observations, k is number of coefficients used to create the series and JB follows a chi-square distribution with 2 degrees of freedom (d.f.). If JB value is greater than the tabular value then the null hypothesis of normal distribution is rejected.

Test for Stationarity: For any analysis on time series data or panel data, unit root or stationarity test is an essential step. We have employed both parametric and non-parametric unit root test in this study i.e., Augmented Dickey-Fuller and Philips-Perron test were used to check stationarity of the data.

a) Augmented Dickey-Fuller test: ADF test (Dickey and Fuller 1979) [4] is a parametric unit root test. The regression equation of this test is:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \quad (2)$$

Where α is a constant, β the coefficient on a time trend and p the lag order of autoregressive process. The null hypothesis is that there is a unit root present in the series, i.e., γ=0 against alternative hypothesis γ<0.

b) Phillips Perron test: In statistics, Phillips-Perron (Peter C. B. Phillips and Pierre Perron) is a unit root test. It is used in time series analysis to test the null hypothesis that a time series is integrated of order 1. Regression equation is as follows,

$$\Delta y_t = (\beta-1) y_{t-1} + u_t \quad (3)$$

Here the null hypothesis is β=1. This test is a non-parametric test for stationarity.

Johansen cointegration test: In statistics, the Johansen test, named after Soren Johansen, is a procedure for testing cointegration of several time series (integrated of order 1 or I(1)). This test permits more than one cointegrating relationship so it is more generally applicable than Engel-Granger test. It is mainly used to test any long run relationship exists between two or more variables. The general VAR(p) form of the model without drift is given by:

$$x_t = \mu + A_1 x_{t-1} + \ldots + A_p x_{t-p} + w_t \quad (6)$$

Where μ is the vector-valued mean of the series, A_i are the coefficient matrices for each lag and w_t is a multivariate noise term with zero mean. Now a Vector error-correction model (VECM) is form by differencing the series:

$$\Delta x_t = \mu + A x_{t-1} + \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_p \Delta x_{t-p} + w_t \quad (7)$$

A is the coefficient matrix of first lag and Γ_i are the matrices for each differenced lag. The test of Johansen cointegration test occurs with two different ways one by trace values and other by eigen values. Null hypothesis of the test is that there is no cointegration exist which occurs when A=0. The rank of matrix A is given by r an in Johansen test we check whether r is zero or not. If r=0 that means no cointegration and if r>0 implies a cointegrating relationship between two or more variables.

Granger's causality test: The Granger causality test is a statistical hypothesis test to determine whether one time series is useful in forecasting another, first proposed in 1969 by Clive Granger. If a time series is a stationary process, then the test is performed using the level values of two or more variables. For non-stationary case, the test is done using first or higher differences.

Suppose S and E are two time series variables and if past values of variable S significantly contribute to forecast the value of another variable E, then S is said to Granger cause E and vice-versa. The test involves in the following:

$$S_t = \gamma_{0+} \sum_{i=1}^{n} \alpha_i E_{t-i} + \sum_{j=1}^{n} \beta_j S_{t-j} + u_{1t} \quad (4)$$

$$E_t = \gamma_1 + \sum_{i=1}^{m} \lambda_i E_{t-I} + \sum_{j=1}^{m} \delta_j S_{t-j} + u_{2t} \quad (5)$$

In both the equations the number of lags to be chosen using an information criterion, such as the Akaike information criterion or schwarz information criterion. The null hypothesis is that S does not granger causes E and vice-versa. It is granger causes if 1) it is significant according to t-test, 2) it and other lagged values of the variable jointly add explanatory power to the model according to an F-test.

ZIVOT-ANDREWS Structural break test: Zivot and Andrews (1992) endogenous structural break test is a sequential test which utilizes the full sample and uses a different dummy variable for each possible break date. The break date is selected where the t-statistic from the ADF test of unit root is at a minimum (most negative). Consequently, a break date will be chosen where the evidence is least favorable for the unit root null. The critical values in Zivot and Andrews (1992) are different to the critical values in Perron (1989). The difference is due to that the selecting of the time of the break is treated as the outcome of an estimation procedure, rather than predetermined exogenously. Following Perron's characterization of the form of structural break, Zivot and Andrews proceed with three models to test for a unit root: (1) model A, which permits a one-time change in the level of series, (2) model B, which allows for a one time change in the slope of trend function, (3) model C, which combines one time change in level and slope of trend function of the series. The recommended three models are given below,

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \Gamma du_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \quad (8)$$

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \Theta DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \quad (9)$$

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \Gamma du_t + \Theta DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \quad (10)$$

Where DU_t is a dummy variable for a mean shift occurring at each possible break date (BD) while DT_t indicates trend shift variable.

$DU_t = 1$ if t> BD
= 0 otherwise

DT_t = t-BD if t> BD
= 0 otherwises

The null hypothesis in all three models is $\alpha=0$, which implies that the series $\{y_t\}$contains a unit root with drift that excludes any structural break, while the alternative hypothesis $\alpha<0$ implies that the series is a trend-stationary process with a one-time break occurring at an unknown point in time.

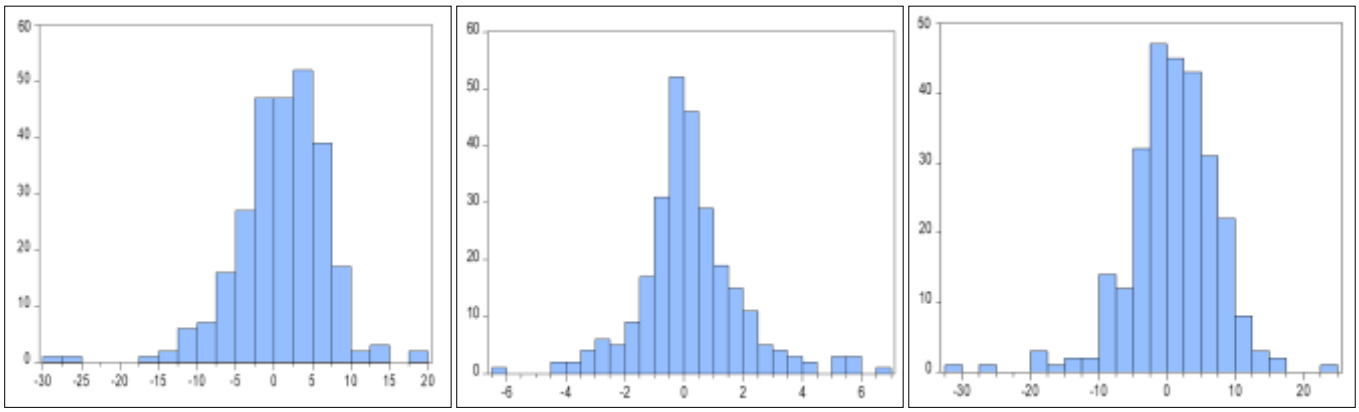
Section 4: Result and Discussion

Descriptive Statistics

In this study, we have checked the descriptive statistics of the three variables. Descriptive statistics mainly gave us the mean, median, S.D, skewness, kurtosis and Jarque-Bera test result. Following table (Table 1) and figure (Figure 1) gave us the details of the variables.

Table 1: Descriptive Statistics

Total Observations: 270	Exchange Rate Returns (USD/INR)	BSE Sensex Returns	Nifty 50 Returns
MEAN	0.223465	0.875836	0.891410
MEDIAN	0.070963	1.297479	1.056450
MAXIMUM	6.565790	19.15382	24.73758
MINIMUM	-6.030368	-28.05136	-30.66649
STANDARD DEVIATION	1.728022	5.873310	6.613558
SKEWNESS	0.469305	-0.905889	-0.762457
KURTOSIS	5.201936	6.499202	6.039974
JARQUE-BERA	64.45697	174.6782	130.1266
PROBABILITY	0.0000	0.0000	0.0000



*__Source:__ Author's own calculation using Eviews10.

Exchange rate returns BSE SENSEX returns NIFTY50 returns

Fig 1: Bar Diagram of the Variables

From the above table and graphs we can observe that the variable exchange rate returns have normal skewness and leptokurtic (peaked curve) (5.2019>3) distribution. The probability value of Jarque-Bera test for exchange rate returns indicates rejection of null hypothesis of normal distribution. BSE SENSEX returns and NIFTY50 returns have negative skewness and leptokurtic. Both BSE SENSEX and NIFTY50 are also not normally distributed as per their probability value.

Unit Root Test

After the descriptive statistics of the sample series, we are going to check the stationarity of the data series. Here we have used both parametric and non-parametric test for the authenticity of the data series. ADF test and Phillps-Perron test are applied in this study. Though both the test is similar to each other, but the primary difference between them is how the tests each manage serial correlation. Phillips-Peron test makes a non-parametric correction to the t-test statistic. Davidson and Mackinnon (2004) report that the Phillips-Perron test performs worse in finite samples than the ADF test. Here we performed both the test one by one.

Augmented Dickey-Fuller Test result (Parametric Test) at level

Table 2: ADF Test Result

	t-statistic	Prob*
Exchange rate returns	-13.14649	0.0000*
BSE SENSEX returns	-13.43452	0.0000*
NIFTY50 returns	-15.91775	0.0000*

*Indicates significant at 1% level *Source: Author's own calculation using Eviews10

Phillips-Perron Test result (Non-Parametric Test) at level

Table 3: PP Test Result

	t-statistic	Prob*
Exchange rate returns	-13.06608	0.0000*
BSE SENSEX returns	-13.50320	0.0000*
NIFTY50 returns	-15.94623	0.0000*

*Indicates significant at 1% level *Source: Author's own calculation using Eviews10

In this study, we have three series namely, Exchange rate returns, BSE SENSEX returns and NIFTY50 returns. We have used both parametric and non-parametric test to check the stationarity of all the above-mentioned series.
According to ADF test, we observe that all three variables are stationary at level with significance at the 1% level. Similar result also occurs in Phillips-Perron test where all the variables are stationary at level.
Now, we can see that both ADF and Phillips Perron test gave us same result that is all the three variables are stationary at level. So, we can now easily check the interlinkage between them using Johansen cointegration test.

Johansen cointegration test
Johansen Cointegration test mainly used to check whether any long run relationships exist between some variables or not. Previously, we have found that all the three variables were stationary at level. Now, we can easily use Johansen cointegration technique to test the long run relationship between foreign exchange market and stock market in Indian context.

Included observations: 266 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Lags interval (in first differences): 1 to 3

Unrestricted cointegration Rank Test (Trace)

Table 4: Trace Statistic Result

Hypothesized no. of CE(s)	Eigenvalue	Trace Statistic	0.05 critical value	Prob*
None*	0.452292	275.9160	35.19275	0.0000
At most 1*	0.214475	115.7804	20.26184	0.0000
At most 2*	0.176228	51.56730	9.164546	0.0000

***Source:** Author's own calculation using Eviews10.
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level

Unrestricted cointegration Rank Test (Maximum Eigenvalue)

Table 5: Max Eigen Statistic Result

Hypothesized no. of CE(s)	Eigenvalue	Max Eigen Statistic	0.05 critical value	Prob*
None*	0.452292	160.1357	22.29962	0.0000
At most 1*	0.214475	64.21306	15.89210	0.0000
At most 2*	0.176228	51.56730	9.164546	0.0000

***Source:** Author's own calculation using Eviews10.
Max-eigenvalue test indicates 3 cointegrating eqn (s) at the 0.05 level
*Denote rejection of the hypothesis at the 0.05 level

In Johansen cointegration test, the null hypothesis is that there is no cointegrating equation. But from the above tables it can be easily interpretated that there is cointegration between Exchange rate returns, BSE SENSEX returns and NIFTY50 returns. Johansen cointegration test gives both Trace and Max Eigen value result and in both cases the trace statistic and Max Eigen Statistic is higher than the 0.05 critical value. So, we can clearly see that there is 3 cointegrating equation at the 0.05 level. The above-mentioned results indicate that there is long run relation between Foreign Exchange Market and Stock Market in Indian context.
From Johansen cointegration test, we observe that there is a long run relationship between Exchange rate returns and BSE SENSEX and NIFTY 50 returns. So, here we check the error correction term to study the convergence and stability of the system.

Error correction model
Firstly, we check the unit root test of the error correction series. From the table we can see that the Error correction series is stationary at level according to Augmented Dickey-Fuller test.

Unit Root test of Error Correction Term

Table 6: ADF Test of ECT

	t statistic	Prob*
Augmented Dickey-Fuller test statistic	**-13.49999**	**0.0000***
Test critical values:		
1% level	-3.4545	
5% level	-2.8720	
10% level	-2.5724	

*Indicates significant at 1% level. *Source: Author's own calculation using Eviews10.

Significance of Error Correction Term
Dependent Variable: D (Exchang Rate Returns)

Table 7: Significance Result of ECT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.39E-06	0.090502	0.000104	0.9999
D(BSE_RETURNS)	-0.119863	0.014840	-8.077234	0.0000
D(NIFTY_RETURNS)	-0.021911	0.012026	-1.821946	0.0696
ECT01(-1)	-0.815238	0.060917	-13.38275	0.0000*

*Indicates significant at the 1% level. *Source: Author's own calculation using Eviews10.

The Error correction series is observed to be significant as is evident from the table that shows that the coefficient of Error correction term is negative (-0.815238) and significant at the 1% level. So, we can say that the speed of convergence of the shocks are 81.52%. It is needless to say that the speed is fair enough and shocks gets corrected in long run at a pretty fast pace.
After successfully checking the long run relationship between foreign exchange and stock market of India we have performed the error correction model, which also gave us satisfactory result. Now, we want to check whether any causal relationship exists between these two markets or not.

Granger causality test:
Granger causality test mainly uses to check whether there is a causal relationship between two variables. It can be bidirectional or unidirectional relationship. In this study, we have checked causal relationship between BSE returns and exchange rate returns and between Nifty returns and exchange rate returns. Following table (Table 8) described the result briefly.

Sample: 2000M01 2022M07

Table 8: Granger causality of BSE and Exchange rate

Null hypotheses	Observations	F-statistics	Prob
BSE returns does not Granger cause Exchange rate returns	269	0.00459	0.9460
Exchange rate returns does not Granger cause BSE returns	269	0.27708	0.5991

Table 9: Granger Causality of NIFTY and Exchange Rate

Null hypotheses	Observations	F-statistics	Prob
Nifty returns does not Granger cause Exchange rate returns	269	7.6807	0.0060*
Exchange rate returns does not Granger cause Nifty returns	269	1.2754	0.2598

*Indicates significant at 5% level.
***Source:** Author's own calculation using Eviews10.

From the above table we can see that the null hypothesis of no Granger cause relationship between BSE SENSEX returns and Exchange rate returns is accepted. So, there is no relationship between BSE SENSEX and Foreign exchange rate (USD/INR) in short run. But there is a unidirectional relationship between NIFTY50 returns and Exchange rate returns. So, we can say that there exists a relationship between Stock market and foreign exchange market (USD/INR) in Indian context for the time period January 2000 to July 2022.

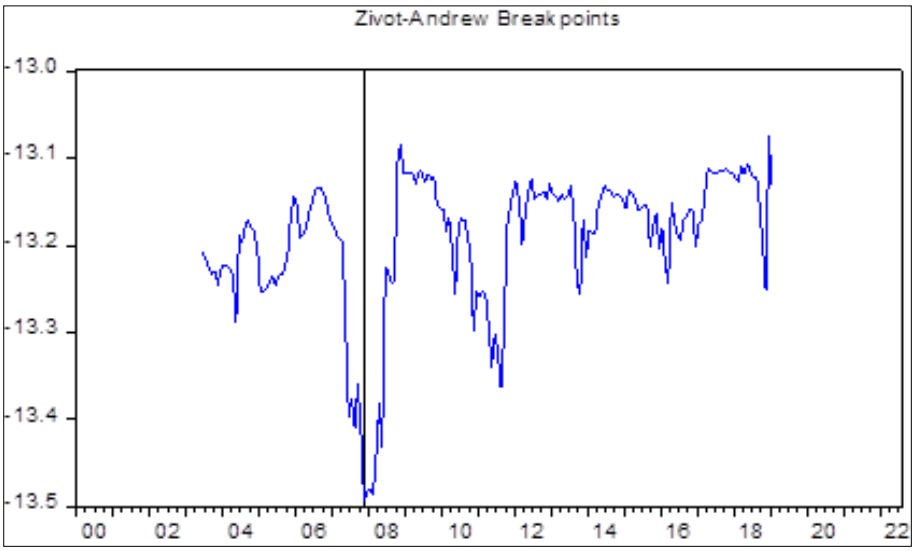
Key Findings

This article delves into the evolving connections between India's foreign exchange and stock markets over the past twenty years, from January 2000 to July 2022. We utilized monthly data of foreign exchange rates and stock indices, employing both Johansen cointegration test and Granger's causality test. While prior research has presented varying views on the relationship between these markets, our empirical findings shed light on a unidirectional link between NIFTY50 and the foreign exchange rate, whereas no discernible connection exists between BSE SENSEX and the foreign exchange rate. Nevertheless, a long-term relationship persists between both markets.

However, to ensure robustness in our analysis, we must consider the potential for structural breaks in the data series. To address this, we implement the Zivot-Andrews structural break test, discussed in the latter part of our study.

Second Part

Zivot-Andrews structural break test
Sample: 2000M01 2022M07
Null Hypothesis: EXCHANGE_RETURNS has a unit root with a structural break in both intercept and trend



***Source:** Author's own calculation using Eviews10.

Fig 2: Zivot-Andrews Test

Zivot-Andrews Structural break test is an endogenous break test. In this test we check for the existence of structural break in the dependent variable of our model that is Exchange rate returns. From the above table and graph, we note that there is a structural break in the Exchange rate returns series. The structural break comes in November 2007 (2007M11). So, we divide the whole data series into two sub samples to arrive that a more robust result. One Sub sample is from January 2000 to October 2007 (2000M01-2007M10) and other is January 2008 to July 2022 (2008M01-2022M07).

Descriptive statistics of both sub samples
Sub sample 1 descriptive statistics

Table 10: Descriptive Statistics Sub Sample 1

Total Observations: 93	Exchange Rate Returns (USD/INR)	BSE Sensex Returns	Nifty 50 Returns
Mean	-0.104646	1.32206	1.4402
Median	-0.06265	2.8987	2.3441
Maximum	2.9597	14.5182	16.1363
Minimum	-4.3588	-15.5444	-19.1146
Standard deviation	1.08823	6.2212	7.0519
Skewness	-0.7968	-0.7555	-0.5480
Kurtosis	5.9189	3.1842	3.1376
Jarque-bera	42.8578	8.9790	4.7294
Probability	0.0000	0.0112	0.094

*__Source:__ Author's own calculation using Eviews10.

Sub Sample 2 descriptive statistics

Table 11: Descriptive Statistics Sub Sample 2

Total Observations: 175	Exchange Rate Returns (USD/INR)	BSE Sensex Returns	Nifty 50 Returns
Mean	0.4014	0.6098	0.5873
Median	0.2317	0.9230	0.6223
Maximum	6.5657	19.1538	24.7375
Minimum	-6.0303	-28.0513	-30.6664
Standard deviation	1.9747	5.7102	6.3907
Skewness	0.3678	-1.0190	-0.9455
Kurtosis	4.1817	8.8423	8.1917
Jarque-bera	14.1310	279.1746	222.6183
PROBABILITY	0.0008	0.0000	0.0000

*__Source:__ Author's own calculation using Eviews10.

Above tables describe the descriptive statistics for the both sub samples. For sub sample 1, it is very much clear that all the variables are negatively skewed and all are leptokurtic (value >3). The probability values of Jarque-Bera test also suggest that all the three variable are not normally distributed. In case of Sub sample 2, exchange rate return is more or less normally skewed but other variables are negatively skewed. All three variables are leptokurtic and as per probability value of Jarque-Bera test all are nonnormal distribution.

Unit root test of both sub samples
Unit root test results Sub-Sample 1

As we mentioned earlier that both parametric and non-parametric unit root tests are applied in this study. Though there is no major difference between them but non-parametric test (Phillips-Perron) makes a non-parametric correction in the t-test statistic. We discussed them one by one in the below tables (Table 11 and 12) for the sub sample periods.

Augmented Dicky-Fuller Test Result (Parametric Test) at level

Table 12: ADF test Sub Sample 1

	t-statistic	Prob*
Exchange rate returns	-6.023627	0.0000*
BSE SENSEX returns	-7.139174	0.0000*
NIFTY50 returns	-8.713416	0.0000*

Phillips-Perron Test result (Non-Parametric Test) at level

Table 13: PP Test Sub Sample 1

	t-statistic	Prob*
Exchange rate returns	-6.023627	0.0000*
BSE SENSEX returns	-7.188596	0.0000*
NIFTY50 returns	-8.763445	0.0000*

*Indicates significant at 1% level *Source: Author's own calculation using Eviews10.

Unit root test results Sub-Sample 2

Augmented Dicky-Fuller Test Result (Parametric Test) at level

Table 14: ADF test Sub Sample 2

	t-statistic	Prob*
Exchange rate returns	-11.09064	0.0000*
BSE SENSEX returns	-11.23971	0.0000*
NIFTY50 returns	-13.08559	0.0000*

Phillips-Perron Test result (Non-Parametric Test) at level

Table 15: PP Test Sub Sample 2

	t-statistic	Prob*
Exchange rate returns	-11.09064	0.0000*
BSE SENSEX returns	-11.30293	0.0000*
NIFTY50 returns	-13.08511	0.0000*

*Indicates significant at 1% level
*__Source:__ Author's own calculation using Eviews10.

From the above table we observe that both BSE SENSEX and NIFTY50 return and foreign exchange rate return series are stationary at level for both the sub samples. The Augmented Dickey-Fuller test and Phillips-Perron test give same kind of result. In both test, the null hypothesis of no unit root is rejected and stationarity of the variables is accepted.
So, after the unit root test that it is clear that all the variables are stationary an are in same order I(0). Now we are going to check the long run relationship between them (for sub sample period) using Johansen cointegration test.

Johansen cointegration test of both sub sample

Included observations: 89 after adjustments and 171 after adjustments
Trend assumption: Linear deterministic trend (restricted)

Unrestricted Cointegration Rank Test (Trace) for Sub sample 1 and 2

Table 16: Trace Statistic Result Sub Sample 1

Hypothesized no. of CE(s)	Eigenvalue	Trace Statistic	0.05 critical value	Prob*
None*	0.480404	103.7706	42.91525	0.0000
At most 1*	0.285713	45.50192	25.87211	0.0001
At most 2*	0.160364	15.55606	12.51798	0.0150

Table 17: Max Eigen Statistic Result Sub Sample 1

Hypothesized no. of CE(s)	Eigenvalue	Trace Statistic	0.05 critical value	Prob*
None*	0.454107	180.2046	29.79707	0.0001
At most 1*	0.239297	76.69271	15.49471	0.0000
At most 2*	0.160529	29.92218	3.841466	0.0000

***Source:** Author's own calculation using Eviews10
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level

Unrestricted cointegration Rank Test (Maximum Eigenvalue)

Table 18: Trace Statistic Result Sub Sample 2

Hypothesized no. of CE(s)	Eigenvalue	Max Eigen Statistic	0.05 critical value	Prob*
None*	0.480404	58.26868	25.82321	0.0000
At most 1*	0.285713	29.94587	19.38704	0.0010
At most 2*	0.160364	15.55606	12.51798	0.0150

Table 19: Max Eigen Statistic Result Sub Sample 2

Hypothesized no. of CE(s)	Eigenvalue	Max Eigen Statistic	0.05 critical value	Prob*
None*	0.454107	103.5119	21.13162	0.0001
At most 1*	0.239297	46.77053	14.26460	0.0000
At most 2*	0.160529	29.92218	3.841466	0.0000

***Source:** Author's own calculation using Eviews10
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level

It is very much clear from the above tables that in both sub samples there is a long-run relationship between foreign exchange market and Stock market of India. The null hypothesis of no cointegration is rejected for both sub samples and both rejected based on trace statistic and Max eigen statistic, as the test statistics values are greater than 0.05 critical values. We can see that there is three cointegrating equations for both sub samples. So, we can easily conclude that there is an interlinkage between exchange rate returns and BSE SENSEX and NIFTY50 returns in long run.

Error correction model of both sub sample

After Johansen cointegration test on both subsamples we conclude that there is a long-run relation between foreign exchange and stock market. So, it is very obvious to check error correction term for convergence of the error term and stability of the system.

Unit Root Test for Error Correction Term (Sub sample 1 and 2)

Table 20: ADF Test of ECT Sub Sample 2

Sub sample 2 No of Observations: 174	t statistic	Prob*
Augmented Dickey-Fuller test statistic	-11.5638	0.0000
Test critical values:		
1% level	-3.4680	
5% level	-2.8780	
10% level	-2.5756	

Table 21: ADF Test of Sub Sample 1

Sub sample 1 No of Observations: 92	t statistic	Prob*
Augmented Dickey-Fuller test statistic	**-6.1928**	**0.0000**
Test critical values:		
1% level	-3.5030	
5% level	-2.8932	
10% level	-2.5837	

***Source:** Author's own calculation using Eviews10

Significance of Error Correction Term (Sub sample 1 and 2)

Dependent Variable: D(EXCHANG RATE RETURNS)

Table 22: Significance of ECT Sub Sample 1

Variable (Sub sample 1)	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.010996	0.097314	-0.112992	0.9103
D(BSE_RETURNS)	-0.047355	0.014186	-3.338238	0.0012
D(NIFTY_RETURNS)	-0.014095	0.011208	-1.257607	0.2119
ECT01(-1)	-0.602068	0.098098	-6.137402	0.0000*

Table 23: Significance of ECT Sub Sample 2

Variable (Sub sample 2)	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009666	0.125093	0.077267	0.9385
D(BSE_RETURNS)	-0.174255	0.022638	-7.697616	0.0000
D(NIFTY_RETURNS)	-0.012826	0.019141	-0.670085	0.5037
ECT02 (-1)	-0.878528	0.076873	-11.42830	0.0000*

*Indicates significant at the 1% level. *Source: Author's own calculation using Eviews10

Firstly, we conduct a unit root test on the error correction series, and based on the table above, it's evident that the series is stationary for both sub-samples. Next, we assess the stability of the error correction term, using exchange rate returns as the dependent variable. The results are quite reassuring for both sub-samples. In sub-sample 1, the speed of convergence stands at 60.20%, with a negative and significant value. Similarly, in sub-sample 2, the rate reaches 87.85%, also displaying a negative and significant trend. This indicates that the convergence speed is robust for both sub-samples, comparable to the full sample data (which records 81%). The primary aim of our study, examining the interconnections between the Indian foreign exchange and stock markets, is substantially met here. The Johansen Cointegration test reveals a long-term relationship between the Indian Forex and stock markets for both sub-samples, with a particularly strong convergence speed noted in sub-sample 2 (87.85%). Consequently, we proceed to explore the causal relationship between these two markets for both sub-sample periods, building upon the initial findings of our study.

Granger causality test of both sub sample

We have already mentioned that Granger causality test used to check causal relationship between variables. Here we checked granger causality between the variables for both the sub samples. Table 24 and 25 described the result of the test.

Granger Causality test Sub Sample 1

Study Period: 2000 M01 to 2007 M10

Table 24: Granger Causality Test of BSE, NIFTY and Exchange Rate Sub Sample 1

Null hypothesis	Observations	F-statistic	Prob
BSE returns does not granger cause Exchange rate returns	92	0.04790	0.8273
Exchange rate returns does not granger cause BSE returns	92	0.01596	0.8998
Nifty returns does not Granger cause Exchange rate returns	92	3.16188	0.0788
Nifty returns does not Granger cause Exchange rate returns	92	0.009933	0.9209

Granger Causality test Sub Sample 2

Study Period: 2008 M01 to 2022 M07

Table 25: Granger Causality Test of BSE, NIFTY and Exchange Rate Sub Sample 2

Null hypothesis	Observations	F-statistic	Prob
BSE returns does not granger cause Exchange rate returns	174	0.00350	0.9529
Exchange rate returns does not granger cause BSE returns	174	0.64168	0.4242
Nifty returns do not Granger cause Exchange rate returns	174	5.47916	0.0204*
Nifty returns do not Granger cause Exchange rate returns	174	1.66349	0.1989

*Indicates significant at 5% level. *Source: Author's own calculation using Eviews10.

From the above tables we can see that the null hypothesis of no granger cause relationship between BSE returns and Exchange rate returns is accepted for both the sub sample period (2000M01-2007M10 and 2008M01-2022M07). But there is a unidirectional causal relationship between NIFTY returns and Exchange rate returns in sub sample period 2 (2008M01-2022M07). Though, the null hypothesis of no granger relationship between them exists in sub sample 1(2000M01-2007M10). So, we can easily say that after the structural break the relationship between NIFTY and Exchange rate becomes more visible and pronounced which in turn implies the linkage between Stock market and Foreign Exchange market in Indian context.

Section 5: Conclusion

The present study is an attempt to check the dynamic relationship between the foreign exchange and stock market of India for the last two decades. In the initial part of our study, we applied Johansen cointegration test and after that we checked error correction model then we used Granger causality test to check any causal relationship exists or not. We finally observed that there is a unidirectional relationship between NIFTY50 and foreign exchange rate in the short run. Johansen test confirmed the long run relationship between these two markets. Error correction model gave us the speed of convergence of error in long run as 81.50%. The second part of our analysis focuses on the structural break. The test by Zivot-Andrews confirms that there was a structural break in November 2007. Hence, we divide the entire data set into two sub samples and continue the analysis using the previous methods of Johansen cointegration, error correction model and Granger causality test. The results were more or less same but there was no causal relationship in the sub sample 1 that is January 2000 to October 2007. So, we can conclude that the interlinkage between the foreign exchange and stock market of India gets more profound in post 2007. From our study we can easily conclude that there is an interlinkage between Forex and stock market in Indian context, which was previously established by many studies (Mishra 2004, Agarwal et.al 2010). But we have introduced Zivot-Andrews structural break test (endogenous break test), which was rarely used. The test result suggested us that the end of 2007 was a structural break period. We can see that before the structural break there was no causal relationship between them but after 2007 there was a causal relationship between Nifty 50 and foreign exchange rate (USD/INR) and the rate of convergence in the error correction term was much more after the structural break. So, it is needless to say that the structural break increases the interlinkage between these two important financial markets. This interlinkage may be good or may be bad for the economy or society. Hope we can see the goodness or badness of this interlinkage in the near future.

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