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The Short-Run and Long-Run Linkages Between The Selected Exchange Rates: Evidence from India

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ABSTRACT

New skills, ideas, and strategies will help many to meet their needs more effectively and bring value. The main purpose of this study is to investigate the evidence of Cointegration and Granger causal relationship amongst Selected Exchange Rates (SERs) i.e., the US Dollar Rupee (USD-INR), the British Pound Rupee (GBP-INR), the Euro Rupee (EUR-INR) and the Japanese Yen Rupee (JPY-INR) using daily exchange rates. This research will help to better manage risk, short term financing and investment decisions. There is no study conducted for daily data by using these four SERs for the period 2002-2021. Unit root test (ADF & PP), Johansen's Cointegration test, and Granger Causality test areused to assess the short and long run relationship between the SERs. ADF and PP tests show that all the four SERs have found stationary at first difference. The results of the cointegration test indicates the existence of long-run relationship between all four SERs. And the results of Granger causality test showed that Uni-directional Causality exists in GBP-INR to USE-INR, JPY-INR to GBP-INR and EUR-INR to USD-INR, Bi-directional causality exists in EUR-INR and USD-INR and no causality exists between JPY-INR and USD-INR & EUR-INR and GBP-INR.

Keywords: Exchange Rates, Cointegration, Unit Root test, Granger causality, Vector Auto regression.

INTRODUCTION

Investing has been adding more attention from both academicians and researchers, that is,it has begun to work at various levels, such as policy makers, regulators, corporate, financial institutions,and investors. To be able to adhere to the concept of investing properly for any country, it requires continuous financial investments at each level.New skills, ideas, and strategies will help many to meet their needs more effectively and bring value.Interest in investing continues to grow, and there is pressure on policymakers, regulators, corporates, investors, financial institutions, mutual fund managers etc., to move on to a more better investing model. Development will depend significantly on investment thinking and implementation, as well as data management. As a result, different policies developed such as prices of a good are set based on demand and supply of that product andintegration between foreign and domestic market has grown significantly.Additionally, rapid developments in technology and innovation lead towards the quick access to international markets. Because of different financial crisis, volatility has been increased in the foreign exchange market and this increases the foreign exchange risk. Exchange rate has been considered as the main factor of the country's economic condition as if exchange rate changes, it will directly affect the policy makers, regulators, firms, investors, financial institutions, mutual fund managers etc. For policy makers, forecasting about the exchange rate is much important to make decisions about the fiscal and monetary policies. For regulators, to know about relationship between exchange rates is helpful in forecasting the future crisis and steps taken to forecast the future crisis. Some firms operate domestically and internationally so their operations depend on the variations in the exchange rates which will affect the wealth of the firm. Market contributors and investors can use the information of relationship between exchange rates to gauge abnormal profit. Financial Institutions and Mutual fund managers need to estimate variance of portfolio which is dependent on the exchange rate volatility. So, it is essential to estimate the association among exchange rates and this will help to better manage their risk, short term financing andinvestment. Even though this topic has been discussed worldwide, there is still a lack of agreement in the literature regarding the relationship between exchange rates.

LITERATURE REVIEW

In a study conducted by [10] adopts historical data of daily closing prices of CAD/USD, GBP/USD, CHF/USD currencies and the result shows there is to exist cointegration and long-term stability relationship among the currencies. Based on the results it is concluded that economy in the three countries has a very close relationship with American economy. [1] used daily data and reported that causality runs from the stock market to the currency market in Indonesia and the Philippines, while in Korea it runs in the opposite direction. No significant causal relation is observed in Hong Kong, Singapore, Thailand, or Malaysia. However, in Taiwan, they detected bi-directional causality or feedback. Furthermore, contemporaneous adjustments are significant in only three of these eight countries. In developed countries, they found significant unidirectional causality from stock to currency markets and significant contemporaneous effects. [7] applies recently developed unit root and cointegration models to determine the appropriate Granger causality relations between stock prices and exchange rates using recent Asian flu data. Coupled with impulse response functions, it is found that data from Japan and Thailand agree with this approach, so that exchange rates lead stock prices with positive correlation. On the other hand, data of Taiwan suggests the result predicted by the portfolio approach: stock prices lead exchange rates with negative correlation. Data from Indonesia, Korea, Malaysia, and the Philippines indicate strong feedback relations while that of Singapore fails to reveal any recognizable pattern. [4] use an unobserved components methodology in a cointegration framework to estimate multilateral equilibrium values. This methodology has been applied to all the major currencies (the euro, dollar, yen, and Canadian dollar) plus the in countries (those already in EMU), and the out countries (those awaiting entry) and found it a suitable tool for exchange rate monitoring. [3] have empirically analyzed the long-run relationship between real exchange rates and real interest rate differentials, using a panel data set for 10 Asian countries. They concluded that the result of panel cointegration test supports the results for individual countries long-run relationship between real exchange rate and real interest rate differentials. [29] examines the stationary of ten Asian and four emerging Foreign Exchange (FX) rates during the 1990s. They suggest the Philip- Perron modified unit root test and the modified ADF test (the ADF-GLS test) as the solutions to the problems of size and power of the conventional unit root test. [15] Foreign exchange rates are examined using cointegration tests over various time periods linked to regime shifts in central

bank behavior and found that the changing nature of cointegrating relationships indicate that certain types of central bank activity do have long-term effects on exchange rates. [23] found that there is no long-run relationship between stock prices and exchange rates, but there is linear Granger causality from stock prices to exchange rates and nonlinear Granger causality from exchange rates to stock prices. [24] employs the ARDL cointegration approach to examine the impact of financial liberalization on the relationships between the exchange rate and share market performance in China and found that both the exchange rate and the money supply influenced stock price, with a positive correlation. [8] investigate the causality in a Granger sense at different time scales between the spot exchange rate and the nominal interest rate differential by using wavelet analysis. They found that there is only substantial evidence of a causal relationship in the long run between the two variables. When using monthly data, this is true in both directions. When considering impulse responses on how the interest rate differential affects the exchange rate, there appears to be some evidence of more negative relationships at the shorter time scales and more positive relationships at the longer time scales. [12] analyzed the effectiveness of exchange rate on macroeconomic variables of Pakistan. They found that there is no long-run equilibrium relationship between exchange rate and inflation, but there exists long-run equilibrium relationship between exchange rate and trade. There is also long-run equilibrium relationship between exchange rate and FDI and causality runs in both directions, Also, there is long-run equilibrium relationship between exchange rate and GDP, but causality does not run in either direction.[26] shown the short run and long run impact of some macroeconomic fundamentals on the exchange rate volatility in Nigeria. The empirical results revealed that the coefficients of the total import, industrial capacity utilization rate, lending rate of commercial Banks, foreign private investment and liberalization policy period are significant in the long run. Whereas the coefficients of external reserves, inflation rate, interest rate, foreign private investment, total import, and industrial capacity utilization rate were significant in the short run. [19] find that there is no evidence of a long run cointegration between stock markets and exchange rates of seven Australasian countries. [2] attempts to identify the relationship between the growth of real GDP, real exchange rate, and oil prices in Bahrain. The study found that long run relationship exists between the growth of Real GDP, International Oil Prices, and Real Exchange Rate (REXR), the real exchange rate is an important variable to the growth of RGDP, and devaluation will improve the

income growth rate of Bahrain in the long run, the model is stable in the short run according to ECM and Bilateral and unilateral causality among the variables of the model is found. [20] investigates the causal relationship of Indian sector based daily returns with Indian rupee-US Dollar Exchange Rates. The study found bidirectional causal relationship between the exchange rate and stock return for each sector except for Pharmaceutical and Media. [17] attempt to understand the impact of recession of 2008 on relationship between exchange rate of US dollar in INR and gold prices in India. The study found that the two variables under study shared bidirectional causality before recession which was lost during the global financial turmoil in 2007 – 2008. [21] reveals that exchange rate and stock price are co-integrated and a long-run equilibrium relationship exists between them. Also, there is bi-directional causality between exchange rate and stock price in both long run and short run. [6] found that there exists a long-term relationship between Sensex returns and Indian-USD Exchange rates and there is a unidirectional relationship running from stock returns to exchange rates. [28] aims to identify the factors that affect gold prices on the Turkish Gold Exchange. It was concluded that gold prices on the Istanbul Gold Exchange are negatively influenced by the Dow Jones Industrial Index and the volatility of the gold prices on the Istanbul Gold Exchange, positively influenced by London Bullion Market Association's gold prices and the Wholesale Price Index. [9] investigates the Granger Causality test to determine the correlation between interest rates and exchange rates with the composite stock volatility measurement of different companies under the Chicago Board Options and Exchange. The result indicates that interest rates positively Granger cause the stock market volatility indices more than in comparison with the exchange rates. [18] analyses co-movement between the real effective exchange rate of South Africa and those of a sample of countries that include the world's major economies as well as emerging and developing economies. The results show that, such co-movement is mixed and inconsistent. [25] investigates the interaction between stock prices and real exchange rates and found a strong long-run cointegration. The test results indicate a long-run bidirectional causality between stock prices and real exchange rates, and a unidirectional causality from the real exchange rates to the stock prices in the short-run. [13] suggests that currency movements are not purely random. There is a factor related to commodities that helps explain movements in exchange rates which goes beyond the information embedded in carry, global uncertainty, and risk appetite. [14] investigates excess co-movements for the

Euro/US dollar and British pound/US dollar exchange rates and found that excess co-movements indeed exist. A long-run analysis on correlations can verify that the correlations dynamics of exchange rates, relative inflation rates, long-term interest rates, economic sentiments and money supply are linked and found that money supply and prices play major roles. Investigation of exchange rate pair, it becomes obvious that non-fundamental factors in exchange rates have an important meaning for modelling foreign exchange rates. [5] examines how international trade links nominal exchange rates and find that trade linkages alone, with uncorrelated shocks across countries, account for 50% of the empirical trade-exchange-rates-correlation slope coefficient. [11] investigates the effect of macroeconomic variables on the exchange rate USD/CYN using yearly time series data for China economy. The results of long-run ARDL indicate that gross domestic product growth and trade openness have a positive effect on the exchange rate USD/CNY while interest and inflation rates have a negative effect on the exchange rate. [16] investigate that either stock price affects the exchange rate and exchange rate affect the stock price. Study finds the long run relationship between the variables in all the countries but there is less evidence of short run relationship between stock price and exchange rate for the selected countries. [27] examining the short-run and long-run dynamic linkages among exchange rates and stock market index in India through a structured cointegration and Granger causality tests. The results reveal that there is no evidence for a stable long-run relationship between NSE NIFTY and the exchange rates under study. However, the VAR-based Granger causality test shows that USD, JPY, and CNY have short-run causal relationship with NSE NIFTY. [22] Steven Sullivan and Terry Boulter (n.d.) develops a model of exchange rate determination within an error correction framework to identify both long- and short-term determinants that can be used to forecast the AUD/US exchange rate. They found that the overnight interest rate differential, Australia's foreign trade-weighted exposure to commodity prices as well as exchange rate volatility are variables identified that are able explain movements in the AUD/US dollar relationship.

RESEARCH OBJECTIVE

The main aim of this study is to investigate the evidence of Cointegration and Granger causal relationship amongst four Selected Exchange Rates (SERs) using the daily spot exchange rates based on Reserve Bank of India (RBI) reference rate and are obtained from the website of RBI - Database on Indian Economy (DBIE). The data span the period from the January 2002 to December 2021 for a

total of 4844 trading days. The four exchange rates examined are the US Dollar Rupee (USD-INR), the British Pound Rupee (GBP-INR), the Euro Rupee (EUR-INR) and the Japanese Yen Rupee (JPY-INR). To investigate the long-term relationship between the SERs, Johansen's cointegration and short-term relationship through Granger Causality test. Empirical results will benefit all concerned in strengthening the theoretical background of the exchange rate relationship, to make decision on their portfolio and to effectively avoid risk.

DATA AND RESEARCH METHODOLOGY

In this study, the intention is to investigate the evidence of Cointegration and Granger causal relationship amongst Selected Exchange Rates (SERs). The daily spot exchange rates based on Reserve Bank of India (RBI) reference rate used in this paper and are obtained from the website of RBI - Database on Indian Economy (DBIE). The data span the period from the January 2002 to December 2021 for a total of 4844 trading days. The four exchange rates examined are the US Dollar Rupee (USD-INR), the British Pound Rupee (GBP-INR), the Euro Rupee (EUR-INR) and the Japanese Yen Rupee (JPY-INR); For the analysis, the daily spot exchange rates are taken in a logarithmic scale. ADF and PP Test for Unit Root, Johansen Cointegration test, VAR Test and Granger causality test employed to check the long run and short run relationship for the SERs. Equations are given in **Table 1**.

Table 1. Methods Employed

Sr. No.	Methods Employed	Model/Formula	Purpose/Use
1	Descriptive Statistics	Mean, Median, Standard Deviation, Skewness, Kurtosis, Jarque-Bera, and Probability	It is used to examining the normality of the SERs
2	Pair wise Pearson Coefficient of Correlation	$\rho\, x, y = \frac{cov\,(x, y)}{\sigma x\ \sigma y}$	It is used to examining short-run co-movement and multicollinearity amongst SERs
3	Unit Root Tests: Augmented Dickey-Fuller (ADF) and Phillips and Peron (PP)	Augmented Dickey-Fuller (ADF) $\Delta\, Y_t = \delta\, Y_{t-1} + \sum_{i=1}^{k} \beta_i\ \Delta Y_{t-1} +\ \mathcal{u}_t$ $\Delta\, Y_t = \alpha_0\ + \delta\, Y_{t-1} + \sum_{i=1}^{k} \beta_i\ \Delta Y_{t-1} + \mathrm{u}_t$	It is used to check whether the data selected for this study are stationary or non-stationary.

		$\Delta Y_t = \alpha_0 + \alpha_1 t + \delta Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + u_t$ Phillips and Peron (PP) $\Delta \tilde{Y}_t = \sum_{i=0}^{p} \alpha_i t^i + \delta \tilde{Y}_{t-1} + \sum_{i=1}^{k} \beta_i \Delta \tilde{Y}_{t-1} + u_t$	
4	Johansen's Cointegration Test	$J_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i)$ $J_{max} = -T \ln(1-\hat{\lambda}_{r+1})$	It is used to test the presence of long-run equilibrium relationship between the SERs.
5	Granger Causality Test	$Y_t = \alpha_0 + \sum_{i=1}^{m} a_i y_{t-i} + \sum_{j=1}^{n} \beta_i x_{t-1} + \varepsilon_t$ $X_t = \omega_0 + \sum_{i=1}^{m} y_i y_{t-i} + \sum_{j=1}^{n} \beta_j x_{t-1} + \varepsilon_t$	It is used to find the direction of causality and short-run relationship between SERs.

The study aims to test the following hypotheses:

H_1: The SERs are not normally distributed.

H_2: Unit root exists in the SERs i.e., data are non-stationary.

H_3: There is no long run equilibrium relationship exists amongst the SERs.

H_4: There is no causality exists amongst the SERs.

DATA ANALYSIS

Table 2 reports the descriptive statistics for the natural logarithm of the selected exchange rates. From the table, JPY-INR exhibits the highest standard deviation (0.096071), followed by USD-INR (0.086820), EUR-INR (0.077738) and GBP-INR (0.048559). The USD-INR and GBP-INR have positive skewness, whereas GBP-INR has skewness close to zero (0.053972) and is likely to be normally distributed.

Table 2. Results of Descriptive Statistics for SERs from Jan 2002 to Dec 2021

Variables	USD-INR	GBP-INR	EUR-INR	JPY-INR
Mean	1.735906	1.928629	1.824739	1.714018
Median	1.703740	1.925385	1.835380	1.736715
Maximum	1.885409	2.025421	1.961270	1.858056
Minimum	1.594061	1.817216	1.619719	1.514415
Standard Deviation	0.086820	0.048559	0.077738	0.096071
Skewness	0.198287	0.053972	-0.303873	-0.332885
Kurtosis	1.530505	2.079164	2.244117	1.706280
Jarque-Bera	467.5843	173.4942	189.8675	427.2734
Probability	0.00000	0.00000	0.00000	0.00000
Observations	4844	4844	4844	4844

Note 1 SERs in logarithmic scale

Other exchange rate series EUR-INR and JPY-INR is founded to have negative skewness. Kurtosis values reveals that all the SERs follow Platykurtic distribution. The Jarque-Bera test of normality is an asymptotic, or large-sample test. Under the **Null Hypothesis H_1** that the SERs are not normally distributed, using probability values, null hypothesis is not rejected for all the four SERs at 5% level of significance.

Figure 1. UDS INR Movement: Jan 2002-Dec 2021

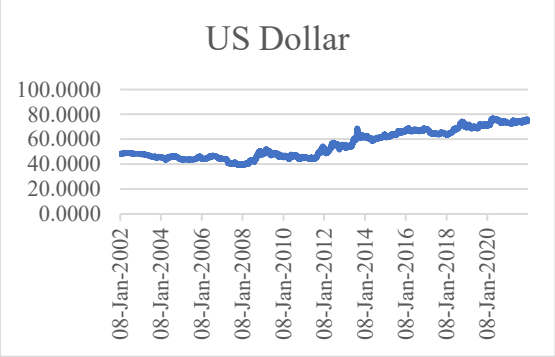


Figure 2. GBP INR Movement: Jan 2002-Dec 2021

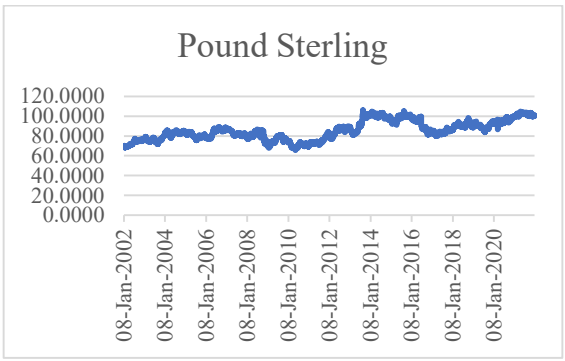


Figure 3. EUR INR Movement: Jan 2002-Dec 2021

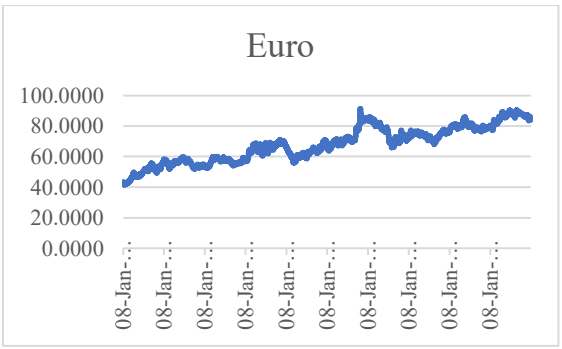
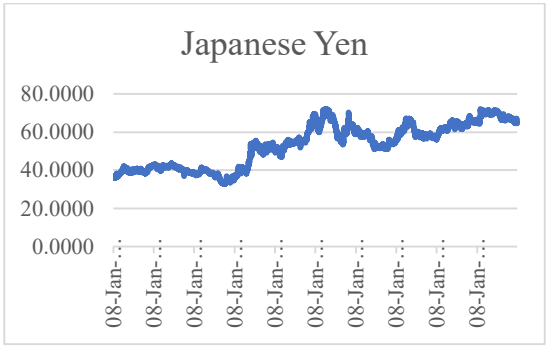


Figure 4. JPY INR Movement: Jan 2002-Dec 2021



The movement of SERs considered in the study are plotted against time from January 2002 to December 2021; see **Figures 1 to 4**. Foreign currency - Rupee from January 2002 to December 2021.

The data series graphs are shown below of the SERs which specify that SERs are not moving around the constant mean and variance. All four SERs appear to display a trend in the mean as they have a clear upward slope, which is an indication of no constant mean. Furthermore, the vertical fluctuations aren't similar at different points of time series, indicating that variance isn't constant. Thus, we can say all the four SERs are non-stationary in the present form.

Result of Pair wise Pearson Coefficient of Correlation for SERs from January 2002 to December 2021 is presented in **Table 3**.

Table 3. Results of Pair wise Pearson Coefficient of Correlation for SERs from Jan 2002 to Dec 2021

Variables	USD-INR	GBP-INR	EUR-INR	JPY-INR
USD-INR	1.000000	0.744210	0.832268	0.819674
GBP-INR	0.744210	1.000000	0.774102	0.529384
EUR-INR	0.832268	0.774102	1.000000	0.865071
JPY-INR	0.819674	0.529384	0.865071	1.000000

Note 1 SERs in logarithmic scale.

The relationship between the all the four SERs is found to be positively correlated. If the pair-wise correlation coefficient between two variables is high i.e., more than 0.8, then there is a chance of multicollinearity.

Here, the Pair wise Pearson Coefficient of Correlation between USD-INR & EUR_INR, USD-INR & JPY-INR and EUR-INR & JPY-INR, is 0.832268, 0.819674 and 0.865071 respectively, indicates the chances of presence of multicollinearity amongst these three pair of exchange rates. The study adopts Augmented Dickey Fuller unit root test [31] and Phillips-Perron unit root test [32] to judge whether logarithmic prices series of SERs have stationary process, i.e., unit root process. Eviews12SV was used to carry out the tests and the results of ADF Test and PP Test are presented in **Table 4** and **Table 5** respectively.

Table 4. Results of Augmented Dickey-Fuller Unit Root Test for SERs from Jan 2002 to Dec 2021

Name of Variable	$\tau_{ADF\ (L)}$		$\tau_{ADF\ (FD)}$	
	Constant	Constant and Trend	Constant	Constant and Trend
USD-INR	-0.29551	-2.65966	-12.39551*	-12.34857*
GBP-INR	-2.22575	-2.86990	-23.27768*	-23.27547*
EUR-INR	-2.12941	-3.59695	-68.91135*	-68.91422*
JPY-INR	-1.51360	-2.28330	-12.91804*	-12.92446*

ADF(L): Augmented Dickey-Fuller test with Level data, ADF(FD): Augmented Dickey-Fuller test with First Difference data

The results are tested at two levels - Constant and Constant & Trend

Note 1: SERs in logarithmic scale.

Note 2: *, **, *** represents the statistical significance at 1%,5% and 10% levels respectively.

For constant model, critical values for the ADF tests are -3.4315, -2.8619, -2.5670 respectively for 1%, 5% and 10% respectively.

For constant and trend model, critical values for the ADF tests are -3.9599, -3.4107, -3.1272 respectively for 1%, 5% and 10% respectively.

Table 5. Results of Phillips-Perron Unit Root Test for SERs from Jan 2002 to Dec 2021

Name of Variable	$PP_{(L)}$		$PP_{(FD)}$	
	Constant	Constant and Trend	Constant	Constant and Trend
USD-INR	-0.18179	-2.45898	-69.34637*	-69.34477*
GBP-INR	-2.04520	-2.75302	-67.99046*	-67.98348*
EUR-INR	-2.12941	-3.62533	-68.90882*	-68.91169*
JPY-INR	-1.47769	-2.25351	-71.73724*	-71.73293*

PP(L): Phillips-Perron test with Level data, PP(FD): Phillips-Perron test with First Difference data

The results are tested at two levels - Constant and Constant & Trend

Note 1: SERs in logarithmic scale.

Note 2: *, **, *** represents the statistical significance at 1%,5% and 10% levels respectively.

For constant model, critical values for the PP tests are -3.4315, -2.8619, -2.5670 respectively for 1%, 5% and 10% respectively.

For constant and trend model, critical values for the PP tests are -3.9599, -3.4107, -3.1272 respectively for 1%, 5% and 10% respectively.

The study uses AIC (Akaike Information Criterion) statistics to select the optimum lag length for ADF test and for PP test Newey-West is used to select Bandwidth. Using unit root tests (ADF and PP), the study rejects the **Null Hypothesis H_2** of unit root in both the model (i.e., constant and constant & Trend) for all the four SERs at the first difference but not for the levels. Hence, all the SERs are first difference stationary series or series are integrated of order one, i.e., I (1).

Optimal Lag Selection:

One of the keyfeatures of VAR model is used to select the optimal lagged length. The following information criteria were used to select appropriate lag length for the cointegrating series: there are Sequential modified LR test statistic (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (BIC) and Hannan-Quinn information criterion (HQC). Choosing the optimal lag length, one must consider that if you use too many lags in your model you are going to lose degrees of freedom and it may lead to serial correlation in the error terms and miss-specification error and too short a lag length may not capture the dynamic behavior of the variables [30]. You choose that criterion which gives you the lower value, the lower the value the better the model. **Table 6** reveals the summary results of VAR lag order selected by all the six-information criterion. To identify the optimal lag length, we need to look for the criteria with asterisks and a lower value. The AIC information criteria shows that the optimum lag length appropriate for this study is 1 with the lowest value i.e.,-37.48999. This means that in generating the short run dynamic model for the SERs, the study chose 1 lag as the optimum lag length indicated by the AIC.

Table 6.Results of VAR Lag Order Selection Criteria for SERs from Jan 2002 to Dec 2021

Lag	LogL	LR	FPE	AIC	SC	HQ
0	90621.25	NA	6.18E-22	-37.48387	-37.47851*	-37.48199*
1	90652.05	61.51823	6.14E-22*	**-37.48999***	-37.46317	-37.48057
2	90667.29	30.43042	6.15E-22	-37.48968	-37.44140	-37.47273
3	90679.80	24.95120	6.15E-22	-37.48823	-37.41850	-37.46375
4	90697.89	36.06381	6.15E-22	-37.48910	-37.39791	-37.45708
5	90712.05	28.18511*	6.15E-22	-37.48833	-37.37569	-37.44879
6	90724.26	24.30647	6.16E-22	-37.48677	-37.35267	-37.43969
7	90734.21	19.76808	6.18E-22	-37.48426	-37.32871	-37.42965
8	90744.36	20.17281	6.19E-22	-37.48185	-37.30484	-37.41970
*indicates lag order selected by the criterion						
LR; Sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

Testing for Cointegration Using Johansen's Methodology

If the series are integrated of order 1, that is stationary in first difference, performing a cointegration test is necessary to establish a long-run relationship. There are two prominent tests for I (1) series in the literature. They are Engle-Granger cointegration test and Johansen cointegration test. This study uses Johansen's co-integration test for checking the possibility of cointegration amongst the SERs. The **Null Hypothesis H_3** in Johansen's co-integration test states that there is no cointegrationequation. The presence of cointegration implies that there is a long-run relationship amongst the SERs. On the contrary, the absence of cointegration indicates that there is no long-run relationship amongst the SERs. Johansen's cointegration test starts on having no cointegration relationship, then at most one cointegration relationship, till at most n −1 cointegration relationship. The Johansen test would give two results i.e., λ_{Trace} and λ_{Max} Eigen statistics. If the value of the λ_{Trace} and λ_{Max} statistics are greater than the critical value, then reject the null hypothesis, otherwise, fail to reject the null hypothesis.

Table 7.Results of Johansen's Co-integration Test for SERs from Jan 2002 to Dec 2021

Cointegration amongst the Variables	Null Hypothesis	λ_{Trace}	λ_{Max}
USD-INR, GBP-INR, EUR-INR, JPY-INR	None*	8213.581 (47.85613)	2134.406 (27.58434)
	At most 1*	6079.175 (29.79707)	2089.062 (21.13162)
	At most 2*	3990.113 (15.49471)	2047.887 (14.26460)
	At most 3*	1942.226 (3.841466)	1942.226 (3.841466)

Notes:

p-value in parentheses ().

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level

Max-eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

The results of the λ_{Trace} andλ_{Max} test statistics is presented in **Table 7** and indicates that the calculated trace test statistics and maximum eigenvalue test statistics are greater than the critical value at 5% probability levels,this implies that the studyrejects the **Null Hypothesis H_3**. The λ_{Trace} statistics indicates fourcointegrating equations and λ_{Max} also identify four cointegrating equations. Hence, the results show that there is a long run cointegration relationship exists amongst the SERs.

The cointegration results indicates that causality exists amongst the SERs, but it fails to show the direction of the casual relationship.

The Pairwise Granger Causality Testis used to check the causal relationship among the SERs and to further examine the direction of causality.

Table 8.Results of Pairwise Granger Causality Testfor SERs from Jan 2002 to Dec 2021

Null Hypothesis	F-Statistic	Prob.	Decision
GBP-INR does not Granger Cause USD-INR	11.1032	0.0009	Rejected
USD-INR does not Granger Cause GBP-INR	1.67132	0.1961	Accepted
EUR-INR does not Granger Cause USD-INR	7.51848	0.0061	Rejected
USD-INR does not Granger Cause EUR-INR	4.92539	0.0265	Rejected
JPY-INR does not Granger Cause USD-INR	1.83781	0.1753	Accepted
USD-INR does not Granger Cause JPY-INR	2.69427	0.1008	Accepted
EUR-INR does not Granger Cause GBP-INR	0.00650	0.9358	Accepted
GBP-INR does not Granger Cause EUR-INR	0.64114	0.4233	Accepted
JPY-INR does not Granger Cause GBP-INR	10.1342	0.0015	Rejected
GBP-INR does not Granger Cause JPY-INR	3.21138	0.0732	Accepted
JPY-INR does not Granger Cause EUR-INR	1.15114	0.2834	Accepted
EUR-INR does not Granger Cause USD-INR	9.68665	0.0019	Rejected

Table 8 reveals the granger causality test result. The null hypotheses are rejected in case the p values are less than 0.05 and in case the p values are more than 0.05, the null hypothesis is accepted. From the statistics given in the table, we can deduce that the **Null Hypothesis H_4** – "USD-INR does not Granger Cause GBP-INR", "JPY-INR does not Granger Cause USD-INR", "USD-INR does not Granger Cause JPY-INR" , "EUR-INR does not Granger Cause GBP-INR" , "GBP-INR does not Granger Cause EUR-INR", "GBP-INR does not Granger Cause JPY-INR" and " JPY-INR does not Granger Cause EUR-INR" cannot be rejected as the obtained p-value is greater than 0.05. However, we can certainly reject the **Null Hypothesis H_4** - "GBP-INR does not Granger Cause USD-INR", "EUR-INR does not Granger Cause USD-INR", "USD-INR does not Granger Cause EUR-INR", "JPY-INR does not Granger Cause GBP-INR" and "EUR-INR does not Granger Cause USD-INR" as the obtained p-value is less than 0.05. The results also reveals that there is unidirectional causality exists among some SERs, there is bi directional causality exists among some SERs and there is no causality exists among some SERs. Uni-directional Causality exists in GBP-INR to USE-INR, JPY-INR to GBP-INR and EUR-INR to USD-INR. Bi directional causality exists in EUR-INR and USD-INR. And no causality exists between JPY-INR and USD-INR & EUR-INR and GBP-INR.

CONCLUSION

This study intended at analyzing the short-run and long-run linkages between the Selected Exchange Rates (SERs) through a Johansen cointegration and a Granger causality test and used the daily spot exchange rates from January 2002 to December 2021 obtained from the website of RBI - Database on Indian Economy (DBIE). The result of Pair wise Pearson Coefficient of Correlation show the relationship between the all the four SERs is found to be positively correlated. ADF and PP test show that all the four SERs have found non-stationary at level but are stationary at first difference. The results of the cointegration test shows the existence of long run relationship among all the four SERs. Granger causality test is also applied to check the causal relationship among the SERs, and resultshave shown Uni-directional Causality exists in GBP-INR to USE-INR, JPY-INR to GBP-INR and EUR-INR to USD-INR. Bi directional causality exists in EUR-INR and USD-INR. And no causality exists between JPY-INR and USD-INR & EUR-INR and GBP-INR. Based on the results, we can conclude that investors can make predictions based on the previous information. To summarize, this relationship of SERs can be used by fund managers, portfolio manager, policy makers, government officials and investors and this will help them to better manage their risk, short term financing and investing.

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