

Determinants of Indian rupee/U.S. dollar exchange rate, its volatility and policy implications

B.S. Project
Final Report

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Abstract

The financial year of 2022-23 saw INR touch a new record low of ₹83 vis-a-vis one dollar with high volatility. The study aims to examine the behaviour of various macroeconomic variables on the value of the INR/USD exchange rate with the increasing amount of capital flow in the Indian financial market, which is affected by the change in the INR/USD exchange rate.

The study using the ADF test, Johansen cointegration test and vector error correction model(VECM) finds that from February 2002 to April 2023, INR/USD is negatively correlated to Gold Prices, Inflation in India, Nifty50, Foreign exchange reserve of India, the 10-year bond yield and 3-month bond yield of USA and positively correlated to WTI crude price and 10-year bond yield of India. Using the VAR model, the paper also finds the relation between macroeconomic variables and INR/USD over a short period during high volatility. It compares the devaluation of INR/USD with other currencies devaluation wrt USD and concludes that INR has performed much better than others during the post covid-19 devaluation of currencies.

Key Words: INR/USD, exchange rate, interest rate, real GDP, Inflation, FIIs, Stock market return, oil prices, gold prices, current account deficit, volatility, commodity prices, macroeconomic factors, econometrics regression model, Johansen cointegration test, ADF test, VECM, time series data

Acronyms: INR- Indian National Rupee, USD- United States Dollar, INR/USD- Value of 1 USD to INR, USD/INR- Value of 1 INR to USD, GDP- Gross Domestic Production, FIIs- Foreign Institutional Investment, NSE- National Stock Exchange, BSE- Bombay Stock Exchange, EGARCH- Exponential Generalized AutoRegressive Conditional Heteroskedasticity, REER- Real effective exchange rate, FDI- Foreign Direct Investment

Problem Statement

In 2022, there was considerable debate about whether the USD was strengthening or INR was losing its value. Through this study, we want to examine and comment on the debate, with the help of the econometrics model, along with finding out about the macroeconomic variables which affect the value of the INR/USD exchange rate with particular emphasis given to the time of high volatility in INR/USD and recommend the policies to counter the high volatility of the INR/USD exchange rate.

Introduction

The main objective of this study is to examine the behaviour of various macroeconomic variables on the value of the INR/USD exchange rate, the underlying movement of the exchange rate, and the cause of volatility in the prices of the INR/USD. By examining the relationship between macroeconomic variables and INR/USD, the study aims to understand the root cause of high fluctuations in the value of INR/USD in recent times and suggest a policy for countering sharp fluctuations in the value of INR/USD. The impact of volatility in various asset prices has increased with the increasing financial integration with the rest of the world. India has witnessed high volatility in the value of INR/USD in the year 2022 -23, with INR reaching its all-time low of ₹83 against 1 USD and excessive exchange rate volatility for a while, causing significant economic risk to the economy and the country's financial development.

India has been part of several series of macroeconomic structural reforms over the period from 1992. Currently, it follows the flexible exchange rate regime, with the RBI intervening in the markets during high volatility in the INR/USD exchange rate. The flexible exchange rate system has two favours in its argument, the first being the competitive nature of the country in international trade, and the second, stabilizing behaviour of speculators would make the exchange rate comparatively stable compared to fixed rates. (Narang,2014)

In this paper, we examine the value of INR to USD because virtually all interbank transactions by market participants, domestic and abroad, involve the purchase or sale of dollars for a foreign currency (Kubarych, 1983). Ehrmann, Fratzscher, & Rigobon (2011) underlined "the dominance of U.S. markets as the main driver of global financial markets: U.S. financial markets explain, on average, more than 25% of movements in euro area financial markets, whereas euro area markets account only for about 8% of U.S. asset price changes." With India expected to be one of the fastest-growing economies in the 2020s, we examine how various economic factors, which, according to economic theory, affect the exchange rate and thus affect the investment pattern in India. It is important to note that a lot of foreign exchange investment powers India's high growth. Therefore the government must ensure that it does not have the dwindling effect of high volatility, which this study tries to explain mathematically and suggests suitable economic measures.

Literature Review

Several studies were conducted over the period to determine the various macroeconomic variables that affect the value of IND/USD, especially after the opening of the economy in 1992.

Mirachandani (2012) tries to review the reasons for the depreciation of INR and the impact of various macroeconomic determinants on the volatility of the exchange rate between INR/USD; The author uses 20-year annual data between 1991 and 2010 of exchange rate and other macroeconomic variables, and using Pearson's correlation analysis finds out that INR/USD is negatively related with interest rate and inflation rate and positively correlated with GDP and foreign direct investment (FDI), while, relation with the current account is found to be negative and insignificant. However, the study has a few limitations as Pearson's correlation analysis only measures the linear relation between the two variables and does not consider any non-linear relationship if it exists. At the same time, the paper does not check for any biases arising due to reverse causality and omitted variable bias. In contrast, the study's use of annual data may not capture the short-term relation between USD/INR.

Murari and Sharma (2013) provide an in-depth analysis of the evolution of the exchange rate mechanism from a fixed to a hybrid exchange rate system for India. The study using the OLS regression method for the period of 2000 to 2013 finds that INR/USD is highly correlated to the money supply, trade balance, Inflation and interest rate. However, the paper does not consider reverse causality and omitted variable bias while performing regression. Sinha and Kohli (2013) apply the OLS regression model to find out that BSE IT and BSE Oil and Gas have no significant relation with USD/INR from Jan '06 to March '12. Also, using OLS for the data from 1990 to 2011 in their research, they stated that inflation differential, lending interest rate, and current account deficit as a % of GDP, and % change in public debt have a considerable effect on USD/INR while GDP has negative relation with the exchange rate for the period of 2000 to 2011.

Khera and Singh (2015) find out for using yearly data between 91-92 and 12-13 and Pearson's correlation that inflation rate, lending interest rate, and current account deficit have a negative relation with the exchange rate of INR while FDI and GDP have a positive relation with INR exchange rate. While the study shows its high level of explanation of the reasons for variation in INR exchange rate, it does not take into account the reverse causality and omitted variable bias, and while suggesting the measures to control the devaluation of INR, fails to take into account the broader economic effect of such policies on the Indian economy.

Thakur et al. (2016), using the linear correlation analysis between INR/USD and the variable for the period of 05' to 15' finds a highly positive correlation between INR/USD and external debt

and GDP and a negative correlation between INR/USD and lending interest rate and mild positive correlation between FDI and INR/USD while no significant relationship between Inflation and INR/USD. Like many previous studies, it also uses the yearly data, thus not capturing the short-term effect of macroeconomic variables on INR/USD. It does not take into account reverse causality and omitted variable bias.

Bhandari (2014), based on the data from 2000 to 2013, used the correlation method to find GDP, export growth, money supply and FIIs have a negative correlation with the INR exchange rate, while FDI and Inflation have a positive relation. The author also explains the reason for the INR depreciation through various macroeconomic causes.

Hsingh (2015) finds the determinants of the INR/USD exchange rate using the annual data between 1976 and 2013 using the simultaneous-equation model of demand and supply using the 2SLS method for estimation, Using EGARCH model to estimate the conditional variance of the exchange rate, the author finds INR/USD is positively related to U.S. real government bond yield, Indian real GDP, U.S. real stock prices and expected INR/USD exchange rate, and is negatively related to Indian real Interest rate, U.S. real GDP and Indian real stock prices. While the paper provides detailed answers to various variables that affect the INR/USD exchange rate, it has limitations in the view that it considers only the yearly average of all variables, thus not capturing the short-term volatility and how it is affected by various variables, while fails to consider India's policy on the exchange rate was significantly different pre and post-1992 liberalization but uses the data from both periods. The study also assumes that demand and supply of INR/USD is the only factor determining the exchange rate while not considering the omitted variable and reverse causality biases.

Dua and Sen (2006) examine the relationship between the Real Effective Exchange Rate (REER), the level of capital inflows and their volatility, government expenditure, current account surplus and money supply for the Indian economy between the period 1993 Q2 to 2004 Q1, they found using Granger causality test and Vector Error Correction Model (VECM) that variables are cointegrated, and each granger affects the REER.

Suthar (2008), using monthly time series from April '96 to June '07 using the linear econometric model, finds that increases in the difference between call rate and bank rate lead to the appreciation of INR, long and short-term interest differential have an insignificant effect, while the rate of change of foreign exchange and foreign reserve have a significant effect on the value of INR.

Mallick (2010), using the Stock-Watson model for the period of 1996 M4 to 2007 M8 shows that growth rate differentials, Foreign Institutional Investments (FIIs), money supply, real bank credit and 3-month forward premium rate affect the INR/USD exchange rate in the long run

QuangMy and Sayim (2016) used Enter and Stepwise multiple regression method to investigate the impact of market fundamentals on the exchange rate between USD/INR, USD/CNY, USD/BRL, and USD/MNX for the period of 2005 to 2014 found out for the USD/INR has a negative relationship with FDI, trade balance and national reserve and positive relation with public debt of India.

Gupta and Mishra (2017), for the period of 1993 to 2014, using annual data and applying Vector Error Correction Model (VECM) along with ADF and Johansen cointegration test, found that in the short run differential interest rate has a significant impact on USD/INR exchange rate while differential GDP and differential Inflation have no significant effect on USD/INR exchange rate.

Williams et al. (2019), from 2000 to 2018 using multiple regression method, examined the relationship of current account balance, net trade, and personal Remittances with the exchange rate for four Asian countries, India, Japan, China and South Korea, and their model can provide significant result for India and Japan while is ultimately rejected for South Korea.

Kumar and Aluvala (2020) finds the impact of economic variables on the exchange rate using regression analysis and analysis of variance (ANOVA) technique on USD/INR found that from 2007 to 2019 Inflation, import growth explains USD/INR exchange rate in a heavy correlation while GDP, call money rate, and export growth have no significance on USD/INR.

Jain et al. (2016), using the DCC-GARCH model and non-linear causality test for the period of 2006 to 2015, found a heavy correlation between crude prices and INR/USD exchange rate and a fall in gold prices found to cause depreciation of INR which, in turn, causes fall of Sensex 30 and a fall in crude prices causes depreciation of INR and fall in the stock market.

Jaiswal (2022), in collaboration with the RBI working paper series, studies the causal linkages of domestic and global market indicators with INR exchange rate using the hybrid approach developed by Nishiyama et al. and Jeong et al., also test for Granger causality in mean and causality in quantile. The author uses the daily data between April 2, 2002, to May 29, 2020. The author finds using the causality-in-quantile test, in mean (return) and variance (volatility), that WTI oil prices predict exchange rate for a much more extensive quantile range compared to Brent oil, but in variance, Brent oil predicts over volatility higher Range than WTI prices, Gold prices predict the exchange rate return at all points except at extreme tail ends. In contrast, for variance, it only predicts causes for medium to moderate high quantity. BSE and NSE index return predict the exchange rate at almost all quantiles, while in volatility BSE index affects more than NSE. In contrast, S&P 500, MSCI, and FTSE 250 predict and affect volatility heavily, Net portfolio investment flows predict the exchange rate and its volatility for the quantile range 0.1 to 0.85, India VIX predicts the exchange rate for the entire distribution while S&P 500 VIX predicts for quantile range 0.15 to 0.80.

Literature Review Conclusion

From the literature review, one thing which is readily observable for most of the earlier studies (pre-2016) except for Dua and Sen (2006) and Mallick (2010), all the studies have used the linear relationship to find out the effect of various macroeconomic variables on the INR/USD exchange rate, and have not taken into account the possible non-linear relationship between them, thus leaving the research and equations open to the reverse causality and omitted variable bias, which going by the economic theory will be present and therefore makes those studies less reliable. However, these studies provide a base for further research. While the research paper by Dua and Sen (2006), Mallick (2010) has identified and used the Granger causality test and ADF and Johansen cointegration test to account for biases but have just provided the correlation exists between macroeconomic variable and INR/USD and have not shown the effect of they have on the exchange rate.

New studies have made a great effort to remove the reverse causality and omitted variable bias but have reduced the number of variables compared to old studies and are much more focused on finding whether the variables are correlated. All the studies except that of Jaiswal (2022), Dua and Sen (2006), Mallick (2010), and Suthar (2008) use the annual average of all the variables for their research, thus taking out the volatility effects and short-term effects of the variables in their respective studies, While Dua and Sen (2006) use the quarterly average to find out the relations, making it better than the other studies. However, it also takes out many effects of volatility in such a scenario; Mallick (2010), and Suthar (2008) use monthly, and Jaiswal (2022) uses daily time series macroeconomic variables data making it much more efficient to take into account the short term effects of variables on the exchange rate.

Out of all the studies study by Jaiswal (2022) is the latest and can be considered the most pioneered, where the effect of each variable on the mean and variance of the exchange rate is defined by the Range of quantile the variable affecting it. However, it does not tell us the effect of that variable directly on the exchange rate.

Research Gap

As per IMF currently, India follows the flexible exchange rate regime, but studies to the best of my knowledge when analyzing the data for their effect on the exchange rate didn't take into account that India before the liberalization had a Pegged Regime between 71' and 92' and Par value system between 47'and 71', thus because of earlier exchange rate regime it is safe to assume that INR was overvalued even after liberalization for quite some time (as the major reason for liberalization in 92 was to make exports competitive and increase foreign exchange reserve which was on brink of collapse) and thus the change in macroeconomic factors might not show the proper effect they are supposed to have on the value of INR/USD exchange rate till the

INR/USD does not reach the value which it should have been if there would have been flexible exchange rate system adaptation along with rest of the world, no study mention that it can cause the variation in the results and do not take into account the sudden drastic changes which county's economy and thus the macroeconomic variables saw during the time period of liberalization in 90s.

While the studies have taken into account the shock caused by the INR/USD exchange rate by the dotcom bubble crisis, the Asian financial crisis of the late 90s, the global recession of 2008 and the Eurozone crisis of early to mid-2010s, no study has taken into account the sudden shock in Inflation in India due to oil prices between 2010 and 2014 during that period the subsidies provided on petrol and diesel was stopped permanently on June '10, and Oct '14 respectively which led to high and unforeseen Inflation thus significant spillover effect of that on the value of the INR/USD exchange rate and coupling it with Eurozone crisis made it one of the worst period INR has seen in post-independent India.

Theoretical Framework

The Indian economy has gone through various changes since its independence, especially after the opening of the economy in 1992, which saw a massive influx of investment made in the country over the years and passing decades and has become more and more integrated into the international economy, market behaviour, expectations and shocks. With different economic phases of the country, India has adopted different exchange rate mechanisms over the years to keep in check the economic development objectives while managing the currency valuation and protecting the interest of its people. However, there have been many instances when exchange rate mechanisms failed or changed very late, all due to the economic crisis 1992.

According to the Reserve Bank of India (RBI), India followed the Par-Value system between 1947 to 1971, in which INR external par value was fixed in terms of gold with the pound sterling as the intervention currency. Following the breakdown of the Bretton-Woods system Indian government adopted pegged regime in 1971 under which INR was pegged to the pound sterling in December 1971, which later, to ensure the stability of the Rupee and avoid the weaknesses associated with a single currency peg, was changed to the basket of currency peg and was followed till the economic crisis of 1992-93. Following the crisis Indian government adopted the market-determined exchange rate regime, under which the RBI has often made interventions to try to keep the rapid devaluation of INR in check.

The period after the 1992 reforms till the 2000s saw a continuous decline in the value of INR against USD, while INR remained pretty stable in the early part of the 2000s given the robust state of the economy and heavy investment by foreign investors in Indian markets, INR reached as high as Rs 39 in late 2007. However, the trend was soon reversed following the global

financial crisis in 2008 as foreign investors started pulling their investments following the crisis, which again saw a rapid decline in values of Rs. The period between Jan 2007 to Dec 2008 can be considered one of the most volatile periods in the past two decades, with INR going within heavy from its maxima and minima during that period.

Post 2008 global financial crisis shock on INR/USD, INR recovered somewhat due to the better economic conditions in India wrt rest of the world. INR faced its next depreciation crisis in the year 2013 when due to various domestic factors like slow economic growth, high Inflation fueled by the gradual ending of subsidies provided by the Indian government on petrol and diesel, stagnant reforms and declining foreign investment as well as with the Taper Tantrum crisis after the remark by then U.S. -Fed chief Ben Bernanke led to a very sharp depreciation of INR/USD and saw INR form a record low of 63 against USD.

Post the 2013 crisis, INR remained in the 60s vis-a-vis USD between Jan 2014 to April 2018, after which there was again a sharp depreciation due to the beginning of the U.S. fed rate hike cycle. INR had its subsequent significant depreciation during the start of covid crisis in March of 2020 and formed a low of 77 during that period; then, during the post covid shocks, which are faced by countries around the world with slowing down of economies around the world, increasing inflation rate, disruption of supply chains around the world due to Russia-Ukraine war, and aggressive rate hike by central banks around the world in 2022 saw INR form a low of 83 against USD.

Macroeconomic Factors Affecting the Value of INR/USD

1.) Inflation Rate in India and USA

If Inflation in India rises and rises at a higher rate during standard economic times, with no change in interest rate by the two central banks, it can lead to a depreciation of INR.

In general, if the increase in Inflation is higher in India than in the USA, it can erode the purchasing power of INR. At the same time, it can also lead to a widening of the trade deficit because of the increasing cost of imports, which can lead to the depreciation of INR. Also, an increase in Inflation can lead to the central bank tightening its monetary policy, which will lead to the appreciation of INR in the future. An increase in domestic Inflation will lead to a decrease in purchasing power of the domestic currency, thus leading to the depreciation of the domestic currency. We observe the strong effect of the inflation rate on INR/USD when the inflation rates of India and the USA are outside their

respective acceptable Range as decided by central banks.(For India range is $4\pm2\%$, and For USA acceptable range is $2\pm1\%$)

2.) Interest Rate

An increase in interest rate by the domestic central bank will lead to an appreciation of the domestic currency vis-a-vis the other currency, while the increase in the interest rate by the foreign central bank will lead to the depreciation of the domestic currency.

A positive interest rate differential increases the demand for domestic money (when domestic interest exceeds foreign interest rate) in the exchange of foreign money, which leads to an appreciation of the spot exchange rate. However, it also implies depreciation expectations in the future (Mallick2010), i.e., if the market expects the domestic central bank to decrease the current high-interest rate in the short term, then following anticipation can lead to a depreciation of the domestic currency. An increase in interest rate by RBI should lead to an appreciation of INR, while an increase in interest rate by Fed USA should lead to a depreciation of INR. In contrast, the anticipation of upcoming interest rate changes derived from 3-month bond yield and 10-year bond yield should have the opposite effect, i.e. an increase in long-term bond yield signifies the upcoming high Inflation, which can lead to investors withdrawing and thus weakening of the domestic currency.

3.) Oil Prices

If a country is a net importer of crude, then an increase in crude prices will lead to an increase in demand for the dollar required to buy the same amount of crude, which will cause the depreciation of that currency vis-a-vis USD since India is a net importer of crude oil and increase in crude prices will lead to depreciation of INR, which was evident the sudden rise of crude oil prices post Russia's attack on Ukraine in Feb 2022

The level of effect of oil prices on INR may differ with the choice oil index, i.e. WTI crude price, Brent crude price, and Arab crude price.

For the study, we have chosen the WTI crude prices.

4.) Gold Prices

A decline in the dollar value against other currencies can be interpreted as a gold price increase and vice versa. Thereby, the strong dollar maintains the actual value of gold and controls the price of gold. Gold can protect investors with dollar holdings against exchange rate risk (Baur & McDermott, 2010).

Since it is a dollar-denoted commodity, if gold prices rise, it will make holding USD more expensive, and USD prices will decrease, i.e. INR will appreciate in value.

5.) Stock Market

In the Indian context performance of the Indian stock market can influence the flow of investment in India.

If India's principal stock exchange Nifty50 outperforms the foreign stock market and with positive investor sentiment, it will lead to an increase in demand for INR which will appreciate the INR.

Apart from the above factors, macroeconomic variables such as GDP and current account deficit (both recorded at quarterly intervals) also affect the value of INR/USD according to economic theory; At the same time, it is difficult to predict the effect of GDP; an increase in the current account deficit leads to a depreciation of INR.

Other Factors Affecting the Value of INR

1.) Political Stability

An unstable political situation in the domestic country can lead to a sharp depreciation of the domestic currency of that country in the short run till the political situation stabilizes.

A telling example of the situation can be seen during the 3 months in 2022 for the U.K.'s currency Pound-Sterling when a situation of 3 Prime Ministers in a year led to a sharp depreciation of the pound-sterling in that period for the short run.

2.) Liberalization Process

A close or ineffective liberalization process can lead to the depreciation of the currency of the domestic country as because of slow or ineffective liberalization, exports of that country will become less attractive, leading to less demand for domestic currency in the financial market, which will cause depreciation of the domestic currency.

3.) Global Factors

Various global shocks can lead to sharp appreciation or depreciation of the domestic currency, especially during a global crisis when investors tend to move to gold to hedge against the crisis leads to depreciation of the domestic currency, as is visible from the sharp depreciation of INR wrt USD during the global financial crisis of 2008, covid-19 and the Russia - Ukraine war.

4.) Central Bank Intervention

Central banks intervene in the financial market by buying or selling the currency using foreign exchange reserves to counter sharp variations in currency valuation in a short period. Indian central bank RBI has made such interventions many times to stop the free fall of INR wrt USD in the market.

Data and Methodology

For the following study, we will attempt to find the effect of gold prices, WTI crude prices, CPI India, CPI USA,nifty50, India's foreign exchange reserve, India's 3-month bond yield, India's 10-year bond yield, USA's 3-month bond yield, USA's 10-year bond yield on the value of INR/USD for a monthly variation for the period of February 2002 to April 2023.

INR/USD and WTI crude(USD/Barrel), USA's 3-month bond yield, and USA's 10-year bond yield are obtained from S.T. LOUIS FED, and gold prices are in INR/ troy ounce. They are obtained from World Gold Council, CPI India and CPI USA from the Bank of International Settlements, nifty50 data is obtained from NSE India, and India's foreign exchange reserve is obtained from RBI. India's 3-month bond yield and India's 10-year bond yield are obtained from Yahoo Finance.

To avoid the multicollinearity problem, the variable CPI USA is removed because of its high collinearity with CPI India, in which the correlation between CPI India and CPI USA is 0.97.

So finally, the model to be estimated becomes

$$\begin{aligned} ExR = & \beta_{0t} + \beta_{1t} GOLDPR_t + \beta_{2t} WTICRUDEPR_t + \beta_{3t} CPIIND_t + \beta_{4t} NIFTY50_t \\ & + \beta_{5t} FXRES_t \\ & + \beta_{6t} IND3MONBOND_t + \beta_{7t} IND10YRBOND_t + \beta_{8t} USA10YRBOND_t + \\ & \beta_{9t} USA3MONBOND_t \end{aligned}$$

Hypothesis building:

- The microeconomic theory indicates a negative relationship between INR/USD exchange rate and gold prices. Since gold is priced in rupees in our study, then an increase in gold price should lead to a decrease in the value of USD, i.e. an appreciation for the INR.
- As per the theory, we expect WTI crude price to have a positive correlation with INR/USD, i.e. an increase in WTI prices should lead to depreciation in INR

- We expect CPI India to have a negative coefficient based on the previous study.
- Nifty50 should also have a negative correlation with INR/USD, i.e. an increase in nifty should cause an appreciation of INR wrt USD.
- India's foreign reserve should have a negative coefficient as per economic theory.
- India's 3-month and 10-year bond yields should have positive coefficients, and USA's 3-month and 10-year bond yields should have negative coefficients since they are forward values about market expectation.

Stata 15 is used for the computation of results.

After collecting data, the next steps involved are testing for unit root, long-run cointegration test and error correction models.

Unit Root Test: Since we are working with time series data, we need to check for the variables' stationarity to avoid spurious regression with non-stationary variables. This study uses the Augmented Dickey-Fuller (ADF) unit root test by Said and Dickey (1984). In this test, the null of a unit root (condition for non-stationary) is tested against the alternative of stationarity. The condition for rejecting the null (i.e. for the series to be stationary) is that the test statistic should be less than the critical value (at 5% significance) in the ADF test.

Cointegration Test: After performing the stationarity test, we need to establish whether there exists a long-run relationship between the variables. For this, a cointegration test is required. Here, we will be using the Johansen Cointegration test, where we will be testing the null of having no cointegrating equation against the alternative of the presence of cointegration.

The cointegration test is performed on the level form and not on their first difference (or any difference, for that matter). The decision criteria are at the 5% level, and the null will be rejected when the Trace and Max statistics are greater than the 5% critical value.

The model selected to determine causality (which predicts whether the past values of one variable can be used to forecast another variable) depends on the cointegration test result. If the result shows a long-run relationship, VECM is a better choice model. If no long-run relationship exists among the variables, only the VAR model applies.

Results and Discussion

A. Preliminary analysis

	Mean	Min	Max	Std. Dev.	Skewness	Kurtosis
ExR	56.98	39.267	82.599	12.32163	.3372405	.337240
GoldPr	69214.15	14325.36	164066.5	39961.38	.3413199	2.213466
WTICrude Pr	66.1369	16.55	133.93	24.60509	.2689645	2.311254
CPI_IND	121.4535	62.0549	202.7375	41.57543	.2496963	1.818059
CPI_USA	104.6211	4.047609	139.1219	15.09612	-.8454996	9.62127
Nifty50	7076.991	955.1167	18385.13	4622.17	.7927951	2.884769
FxRes	1.96e+13	2.48e+12	4.88e+13	1.30e+13	.765841	2.601497
Ind3monYie	6.197887	2.93	11.18	1.704779	-.0054791	2.453571
Ind10yrYie	7.288821	5.1	9.316	.9105015	-.4024386	2.612184

US10yrYie	2.972783	0.533	5.406	1.150411	.0366783	2.032437
US3monYie	1.348574	-.01	5.417	1.594037	1.180275	3.21389

Table 1: Descriptive Statistics of all the variables

Source: Estimates by the Author

B. Unit Root Test Results

By applying the ADF test at the level for all variables, we observed all variables accepted the null hypothesis at 5% critical value and at the first difference, all variables rejected the null hypothesis at 5% critical level.

Table 2: ADF test results for monthly series of variables

p-value/variable	ADF (At Level)	ADF (F.D)
ExR	0.2887**	0.0000*
GoldPr	0.9945**	0.0000*
WTICrude Pr	0.1037**	0.0000*
CPI_IND	0.6695**	0.0000*
Nifty50	0.6283**	0.0000*
FxRes	0.9731**	0.0000*

Ind3monYie	0.2320**	0.0000*
Ind10yrYie	0.0698**	0.0000*
US10yrYie	0.1195**	0.0000*
US3monYie	0.4882**	0.0000*

** Probability >0.05 then Null Hypothesis is accepted. * Probability < 0.05, then Null Hypothesis is rejected

Source: Estimates by the Author

C. Cointegration Test Results

Since all variables in the model are integrated of order one I(1), the cointegration test is applicable. Johansen test is carried out with the appropriate number of lags to eliminate serial correlation. According to AIC, three lags are the most parsimonious lag length for the selected variables. Whereas, according to HQIC, one lag is found to be parsimonious. Consequently, a cointegration test includes 3 and 1 lag with intercept and linear deterministic trend. The Johansen cointegration test depends on the Maximum Eigenvalue of the matrix, and the likelihood ratio test, in turn, depends on the Trace matrix.

Table 4 below shows the result of Johansen cointegration tests. The Trace Test indicates 1 cointegrating equation as the null hypothesis of $r = 1$ is rejected, meaning that there is 1 long-run equilibrium relationship between the variables.

Selection-order criteria

Sample: 2002m6 - 2023m3 Number of obs = 250

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-16194.4				9.4e+43	129.635	129.692	129.776
1	-12493.7	7401.4	100	0.000	2.9e+31	100.829	101.453*	102.379*
2	-12348.3	290.78	100	0.000	2.0e+31	100.466	101.657	103.424
3	-12244.6	207.35	100	0.000	2.0e+31*	100.437*	102.194	104.804
4	-12159.1	170.94*	100	0.000	2.3e+31	100.553	102.878	106.328

Table 3: Select order criteria for the cointegration test; Source: Estimates by the Author

Johansen tests for cointegration					
				Number of obs =	253
				Lags =	1
<hr/>					
maximum				trace	critical
rank	parms	LL	eigenvalue	statistic	value
0	20	-12772.025	.	264.3194	250.84
1	39	-12725.014	0.31039	170.2973*	208.97
2	56	-12697.877	0.19307	116.0235	170.80
3	71	-12679.559	0.13481	79.3884	136.61
4	84	-12667.23	0.09286	54.7302	104.94
5	95	-12655.92	0.08553	32.1102	77.74
6	104	-12646.292	0.07329	12.8536	54.64
7	111	-12642.747	0.02764	5.7630	34.55
8	116	-12640.08	0.02086	0.4302	18.17
9	119	-12639.865	0.00170	0.0000	3.74
10	120	-12639.865	0.00000		

Table 4: Johansen tests for cointegration

Source: Estimates by the Author

D. VECM Estimation for Long Run

After confirming a long-run relationship between variables using cointegration tests, the next step is to run the VECM method to estimate the long-run coefficients of this model. Since all the variables are I(1) (confirmed from the unit root tests in the table), we take the percentage changes of all the variables, i.e., $(X_t - X_{t-1}) * 100 / (X_{t-1})$. Results of the VECM are reported in the Table 5.

All the coefficients (except nifty50 and India's 3-month bond yield) are significant even at a 1% significance level, while nifty50 is significant at a 10% significance level.

The model shows that among variables, the inflation rate is the main factor influencing the changes in the value of the INR/USD exchange rate in the long run with the highest coefficient (-7.027329).

The relation between the foreign exchange reserve and INR/USD is also in line with the economic theory where an increase in the country's foreign exchange reserve will lead to the appreciation of the currency (INR), i.e. a decrease in the value of INR/USD.

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
_ce1					
ExcR	1
Gold_Pri	-3.762696	.3517905	-10.70	0.000	-4.452193 -3.073199
WTI_crude	.5335704	.1348341	3.96	0.000	.2693004 .7978404
CPI_ind	-7.027329	1.983863	-3.54	0.000	-10.91563 -3.139029
Nifty50	-.419274	.253769	-1.65	0.098	-.9166522 .0781041
Fx_rese	-1.577265	.5399584	-2.92	0.003	-2.635564 -.5189659
Yield_3mon_ind	.2993419	.2190984	1.37	0.172	-.1300831 .7287669
Yield_10yr_ind	4.454759	.3961902	11.24	0.000	3.678241 5.231278
Yield_10yr_usa	-1.685403	.1298554	-12.98	0.000	-1.939915 -1.430892
Yield_3mon_usa	-.0504905	.0145151	-3.48	0.001	-.0789397 -.0220413
_cons	9.807772

Table 5: Vector error-correction model for INR/USD return Source: Estimates by the Author

As expected per hypothesis, a 1% increase in gold price leads to a decrease in the INR/USD value by 3%. It justifies the currency hedge property and that the decline in the dollar value against rupees can be interpreted as a gold price increase in rupee denomination and vice versa. Next, the value of WTI crude and INR/USD move hand in hand, which is in line with economic theory, as increases in the price of crude for a country that is a net importer of crude results in the depreciation of the currency of that country, in our model, it will cause depreciation of INR wrt USD.

The 10-year bond yield of India and the USA are respectively with positive and negative coefficients as an increase in long-term bond yield is usually taken as a sign of higher Inflation, which leads to investors moving away from investing in assets of that country which leads to depreciation of INR with increases in yield of Indian bonds and appreciation in the value of INR with increases in bond yield of USA bonds.

While nifty50, which is significant at a 10% level of significance, is also in line with the expectation as increases in return on the Indian equity market value lead to increases in investment by foreign investors which in turn increases the demand for INR (domestic currency) leading to the appreciation of INR, i.e. decreases in the value of INR/USD.

This makes the long-run error correction term:

$$\begin{aligned}
 ExR = & 9.807 - 3.762GOLDPR_t + 0.533WTICRUDEPR_t - 7.027CPIIND_t - 0.419NIFTY50_t \\
 & - 1.577FXRES_t + 0.299IND3MONBOND_t + 4.454IND10YRBOND_t \\
 & - 1.685USA10YRBOND_t \\
 & - 0.05USA3MONBOND_t
 \end{aligned}$$

where all the variables are the percentage change from last month (or monthly returns).

E. VAR model Estimation for short Run periods of high volatility

Next, we performed regression analysis between September 2021 to April 2023 to observe the effect of the macroeconomic variable on INR/USD during the recent high volatility post covid-19 period. For this analysis, we dropped Nifty50, USA's 3-month bond yield, and India's 3-month bond yield. We used the VAR model to capture the effect of macroeconomic variables in the short run after performing the ADF test and finding the appropriate lag order, where we found all our selected variables to be non-stationary at the level and stationary at the first difference after the ADF test.

Selection-order criteria								
	Number of obs = 20							
lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-918.19				3.6e+31	92.519	92.587	92.8675
1	-803.358	229.66*	49	0.000	6.9e+28	85.9358	86.48	88.7238
2	.	.	49	.	-.087543*	.	.	.
3	3408.23	.	49	.	.	-326.823*	-325.463*	-319.853*
4	3391.1	-34.272	49	.	.	-325.11	-323.749	-318.14

Table 6: Select order criteria for the VAR model

Source: Estimates by the Author

Based on Table 6 test result for lag order determination, we used the VAR model with lag order 3 to find the results as mentioned in Table 7.

Based on Table 7 of VAR model results from September 2021 to April 2023, during which INR/USD saw high volatility, we find that 1st lag of gold prices has a negative effect on the exchange rate, and 2nd and 3rd lag of gold prices has a positive effect on the value of INR/USD at 1% level of significance.

1st lag of WTI crude has a positive effect, while 2nd and 3rd lag has a negative effect on the exchange rate at a 1% significance level.

Like long-run effects, here also Inflation has the highest coefficient but has a positive effect on the value of INR/USD at 1st lag order at a 1% level of significance, which is according to our stated behaviour, i.e. the effect of Inflation is sharp and different when it is outside its acceptable Range decided by the central bank which was the case during this period.

India's foreign exchange reserve has a negative effect at the 1st and 3rd lag order while a positive effect at the 2nd lag order at a 1% significance level.

India's 10-year bond yield has a positive effect, and USA's 10-year bond yield has a negative effect on all 3 lag orders, respectively, at a 1% significance level.

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
ExcR					
ExcR					
L1.	-1.035852	9.20e-16	-1.1e+15	0.000	-1.035852
L2.	-.00444832	1.38e-15	-3.3e+12	0.000	-.00444832
L3.	.3944279	1.19e-15	3.3e+14	0.000	.3944279
Gold_Pri					
L1.	-.0202983	3.92e-16	-5.2e+13	0.000	-.0202983
L2.	.1352791	3.72e-16	3.6e+14	0.000	.1352791
L3.	.0118318	3.54e-16	3.3e+13	0.000	.0118318
WTI_crude					
L1.	.0012812	1.78e-16	7.2e+12	0.000	.0012812
L2.	-.0443333	1.65e-16	-2.7e+14	0.000	-.0443333
L3.	-.0585534	6.54e-17	-8.9e+14	0.000	-.0585534
CPI_ind					
L1.	2.095465	2.78e-15	7.5e+14	0.000	2.095465
L2.	0	(omitted)			
L3.	0	(omitted)			
Fx_rese					
L1.	-.3607068	3.41e-16	-1.1e+15	0.000	-.3607068
L2.	.1991785	4.42e-16	4.5e+14	0.000	.1991785
L3.	-.5029973	6.38e-16	-7.9e+14	0.000	-.5029973
Yield_10yr_ind					
L1.	.0442697	6.09e-16	7.3e+13	0.000	.0442697
L2.	.2414455	7.17e-16	3.4e+14	0.000	.2414455
L3.	.2981678	6.00e-16	5.0e+14	0.000	.2981678
Yield_10yr_usa					
L1.	-.032987	1.00e-16	-3.3e+14	0.000	-.032987
L2.	-.0121001	1.37e-16	-8.8e+13	0.000	-.0121001
L3.	-.0426816	1.22e-16	-3.5e+14	0.000	-.0426816
_cons	.0557631	1.63e-15	3.4e+13	0.000	.0557631

Table 7: Vector Autoregression Test Results for the Period of Sep21 to April 23 Source: Estimates by the Author

F. Comparison with other countries' exchange rate

Now we will be comparing the change in valuation of currencies of QUAD nations, BRICS nations, Euro, Pound-Sterling, Mexican Peso, South Korean Won and Indonesian Ruppee wrt USD post covid-19 and compare and evaluate them with changes in INR/USD.

For comparison among countries, we selected Jun '21 to Apr '23. The period is chosen differently than the one chosen for INR/USD in the previous section for short-term estimation as some countries started experiencing the devaluation as early as Jun '21 in their currencies wrt USD.

Based on the results from Table 8, we observe that INR/USD has devalued 12.26% on comparison between its maximum and minimum value, only bettered by IDR/USD at 10.83% and similar to CAD/USD at 12.02% and CNY/USD at 13.34%. In comparison, other currencies exchange rates have devalued relatively more from the INR/USD over the period, with RUB/USD the most depreciating at 64.34% wrt its minimum value followed by other significant devaluation of JPY/USD at 33.86%, ZAR/USD at 31.23%, KRW/USD at 27.03%, GBP/USD at 23.97%, EUR/USD at 22.27%, AUD/USD at 19.98%, and BRL/USD and MXN/USD at 18.93% and 15.64% respectively.

Based on Table 9, INR/USD has the lowest kurtosis meaning it has the least heavy tails compared to others, and data points are more evenly spread out compared to other currency exchange rates, in which exchange rates with high kurtosis are likely to have more extreme values or a heavily pronounced tail either on left or right side of mean depending upon the sign of their skewness.

Countries with positive skewness will have more extreme values to the right of the mean, while those with negative skewness will have more extreme values to the left of the mean. Higher kurtosis implies that the exchange rate may exhibit more volatility and the potential for abrupt and significant changes, making the currency exchange rate with low kurtosis less likely to have abrupt price movements than those with high kurtosis.

Based on the data, we can confer that INR, like all currencies, has devalued wrt USD post covid-19 but has performed relatively much better than both in terms of its percentage devaluation and presence of extreme values when compared to the mean based on its kurtosis, and the spread of Range compared to the relative spread of inter-quartile Range from table 8.

Among the important global economic groups such as QUAD and BRICS, of which India is a vital part, we can conclude that INR has performed best among all currencies in the group vis-a-vis the USD during the post covid-19 period and is also one of the top-performing currencies among G-20 nations.

	The relative distance of maximum from the minimum value	The relative size of Range compared to the central spread
INR_USD	12.2608	25.2626
EUR_USD	22.2769	163.0429
GBP_USD	23.9709	90.3495
CAD_USD	12.0204	76.5553
JAY_USD	33.8624	76.4488
AUD_USD	19.9858	125.7366
KRW_USD	27.0315	144.4791
CNY_USD	13.3463	80.0196
RUB_USD	64.3463	136.9197
ZAR_USD	31.2396	74.0295
BRL_USD	18.9319	289.173

IDR_USD	10.8317	122.5768
MXN_USD	15.6464	235.8464

Table 8: Percentage devaluation of currencies and relative size of Range compared to iqr

Source: Estimates by the Author

stats	INR_USD	EUR_USD	GBP_USD	CAD_USD	JAY_USD	AUD_USD	KRW_USD
mean	77.91979	.9182945	.7879244	1.295978	125.6278	.7048707	1252.253
max	82.59947	1.015011	.8840217	1.368935	147.0515	.7643455	1426.065
min	73.57818	.8300923	.7130879	1.222041	109.8527	.63703	1122.607
skewness	.1672675	.154111	.202549	.3479485	.059393	-.2253352	.4013218
kurtosis	1.385609	2.00627	1.79814	1.757017	1.591219	2.215083	2.335396
sd	3.40043	.0543264	.0533347	.0446405	12.27019	.0324488	81.40462
iqr	7.201952	.0703259	.0898283	.0832071	21.0819	.0564286	124.1424
range	9.021292	.1849191	.1709339	.1468941	37.19877	.1273155	303.4577

stats	CNY_USD	RUB_USD	ZAR_USD	BRL_USD	IDR_USD	MXN_USD
mean	6.660173	70.30558	16.16662	5.220227	14762.74	19.90819
max	7.190185	84.0851	18.25946	5.654876	15737	20.926
min	6.343553	51.158	13.91307	4.754719	14199	18.09482
skewness	.45064	-.4218234	.146023	.1761175	.7545904	-1.049096
kurtosis	1.942838	2.528647	1.678175	2.971924	2.369299	3.363149
sd	.2769049	8.508123	1.357199	.213244	479.8411	.7478465
iqr	.470355	13.898	2.497595	.2313143	690.995	.8430221
range	.8466324	32.9271	4.346388	.9001571	1537.995	2.831185

Table 9: Descriptive Statistics of Exchange Rate Source: Estimates by the Author

Conclusion and Discussion

Over the years, we have observed fluctuations and sharp movements in INR/USD. The study helps in explaining the movement of INR/USD with the help of various macroeconomic variables. We, through conducting the ADF test, Johanson cointegration test and VECM test for the monthly period between February 2002 to March 2023, that macroeconomic variables gold prices, cpi India, India's foreign exchange reserve, USA's 10-year bond yield and USA's 3-month bond yield has a negative correlation with the INR/USD in our estimation equation with all these variables showing significance at 1% level of significance, while WTI crude price, India's 10-year bond yield has a positive correlation with INR/USD at 1% level of significance, while NIFTY 50 has a negative correlation with INR/USD at 10% level of significance, all which explains according to economic theory.

We also found for the high volatility period of September 2021 to April 2023 the effects of variables on the exchange rate via the VAR model. Except for CPI India, all variables have the same correlation with the exchange rate (in terms of the direction of their effect) at 1st lag order, while Inflation in a high volatility period during which it was outside its acceptable Range has a positive effect at 1st lag order on the exchange rate of INR vis-a-vis USD.

To comment on the recent discussion of whether the INR has lost its value or USD has strengthened, we compared INR devaluation to other currencies devaluation wrt USD over June '21 to April '23 and concluded that INR though has devalued compared to USD but so has all the other major currencies. Also, INR has performed much better compared to all the currencies around the world in terms of its relative extreme values during the period and relative variation in its Range compared to the inter-quantile Range; thus, we can conclude that the United States Dollar has strengthened over the period rather than INR alone getting devalued

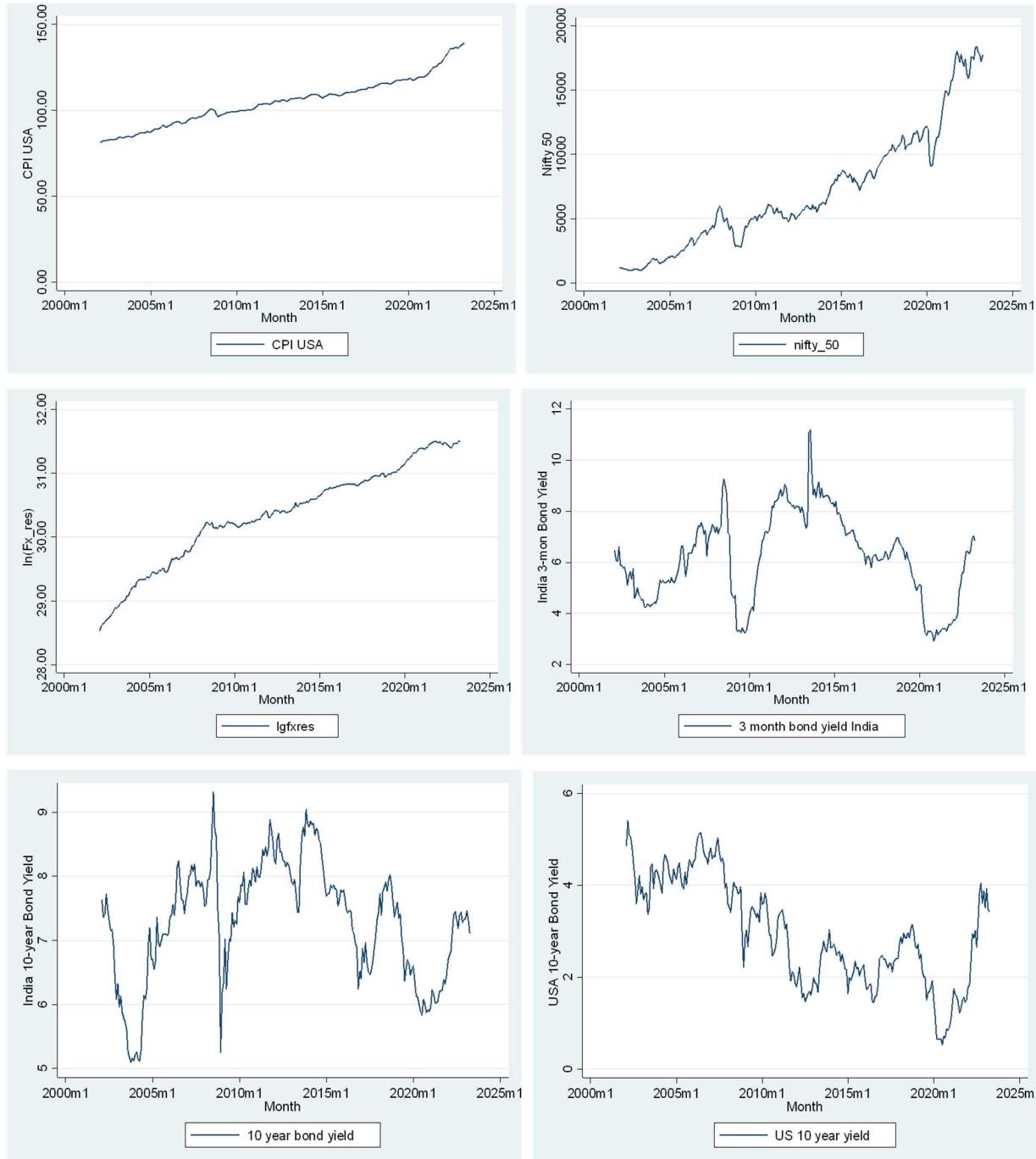
The study does not consider the devaluation of INR as a bad thing for the Indian economy, rather devaluation of INR for the highly growing economy is good for the overall increase in export of the Indian economy. The study considers the sudden fluctuations and sharp devaluations to be bad for the economy as they can lead to the exit of foreign investors, loss for the Indian companies operating at the global level while also making the financial market unattractive due to high volatility, a sudden increase in current account deficit which in turn cause the downfall in GDP due to various reasons as explained in the paragraph above.

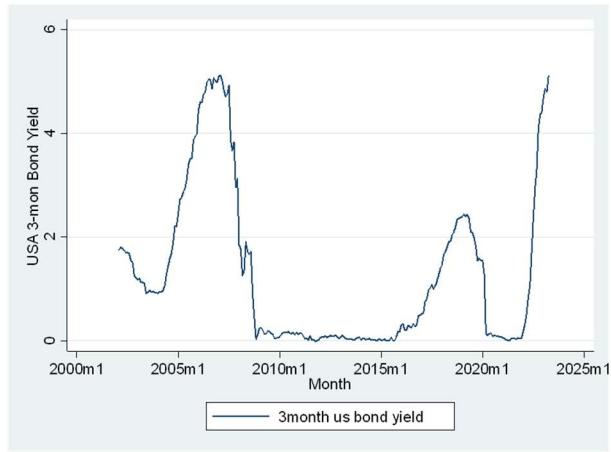
Based on current and previous studies, appropriate fiscal and monetary steps should be taken to control the macroeconomic factors responsible for affecting the value of INR to ensure that INR does not appreciate or depreciate at high volatility, which can disrupt the Indian economy due to the various factors as tested through the VECM and VAR model of the current study.

Appendix

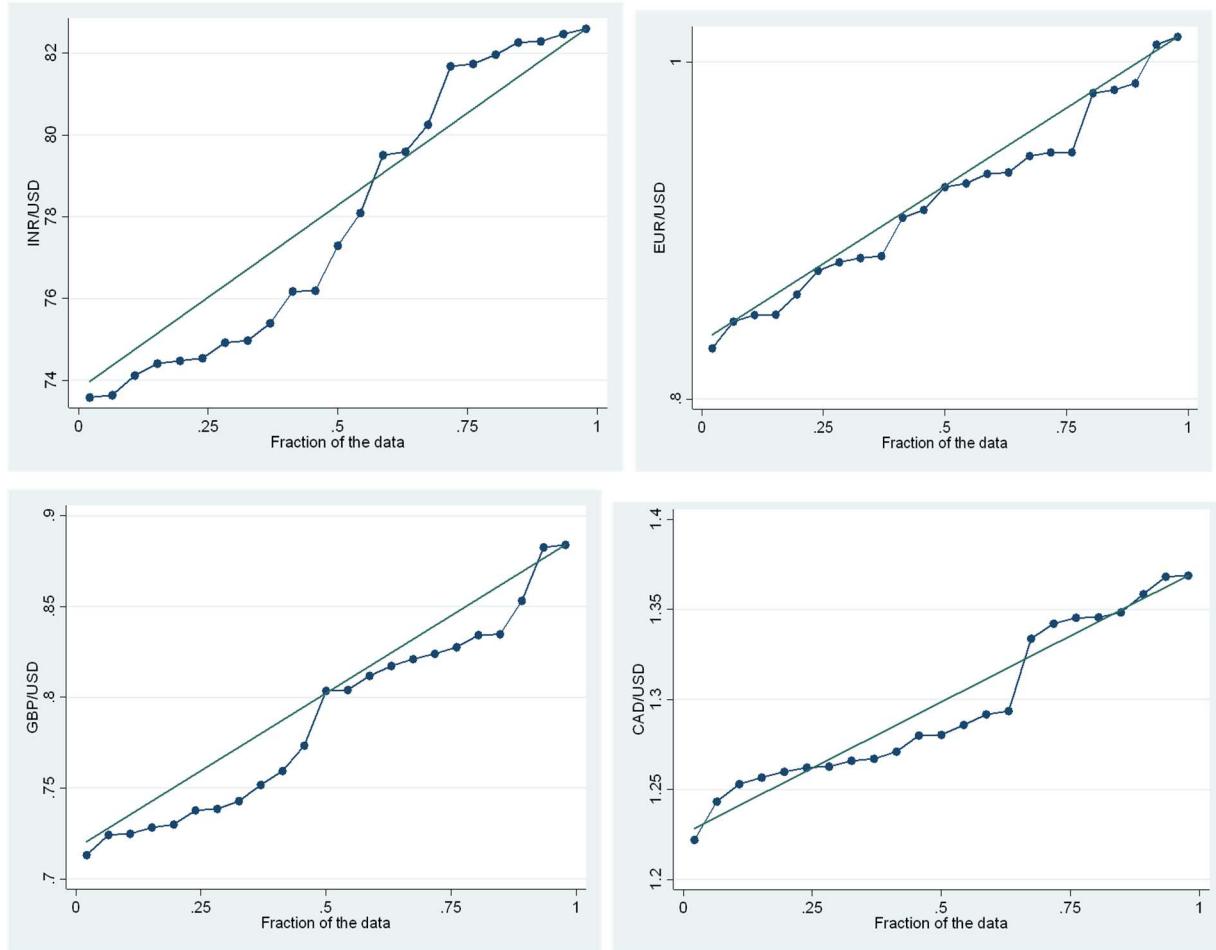
Time Series Graphs of various variables over Feb '02 to April '23

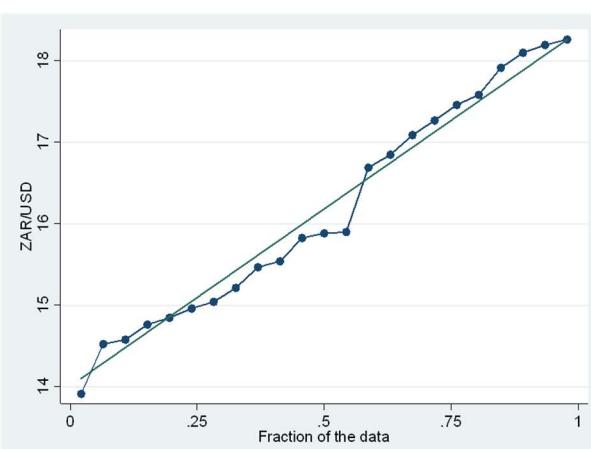
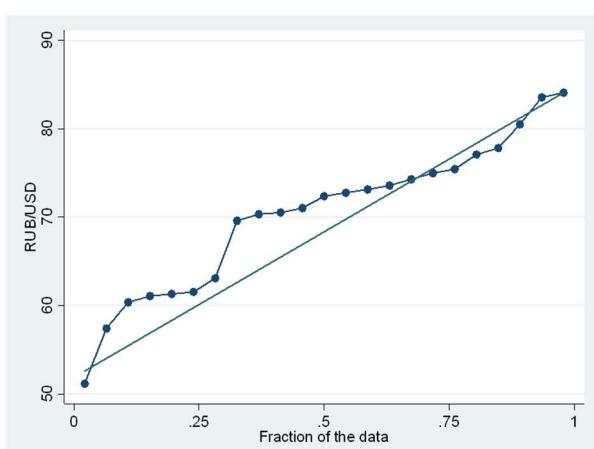
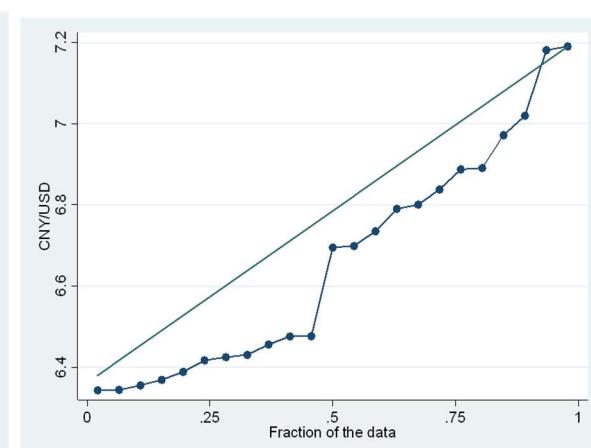
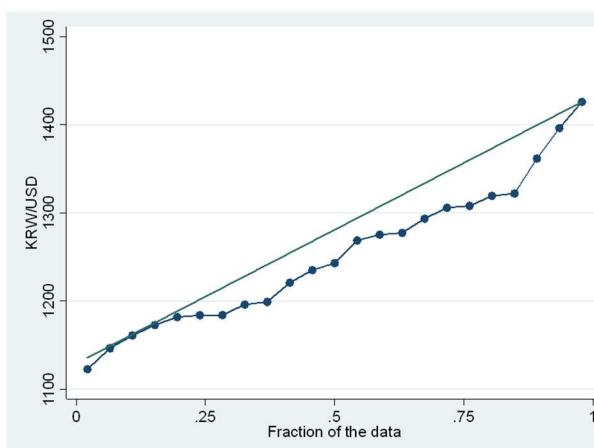
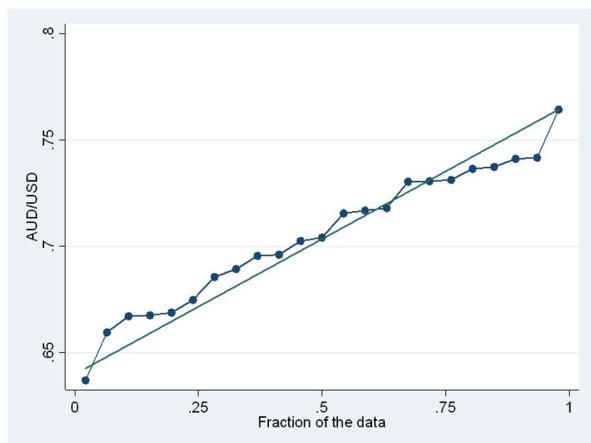
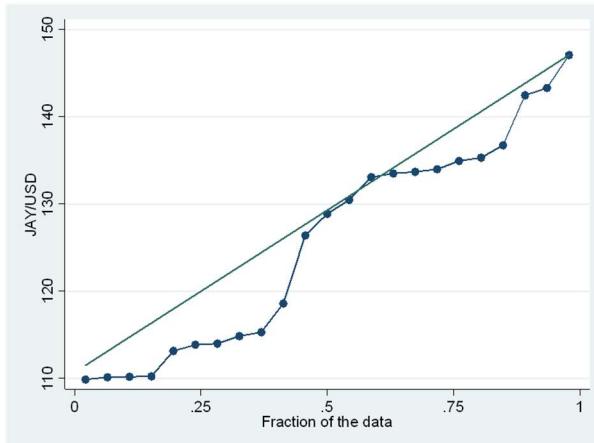


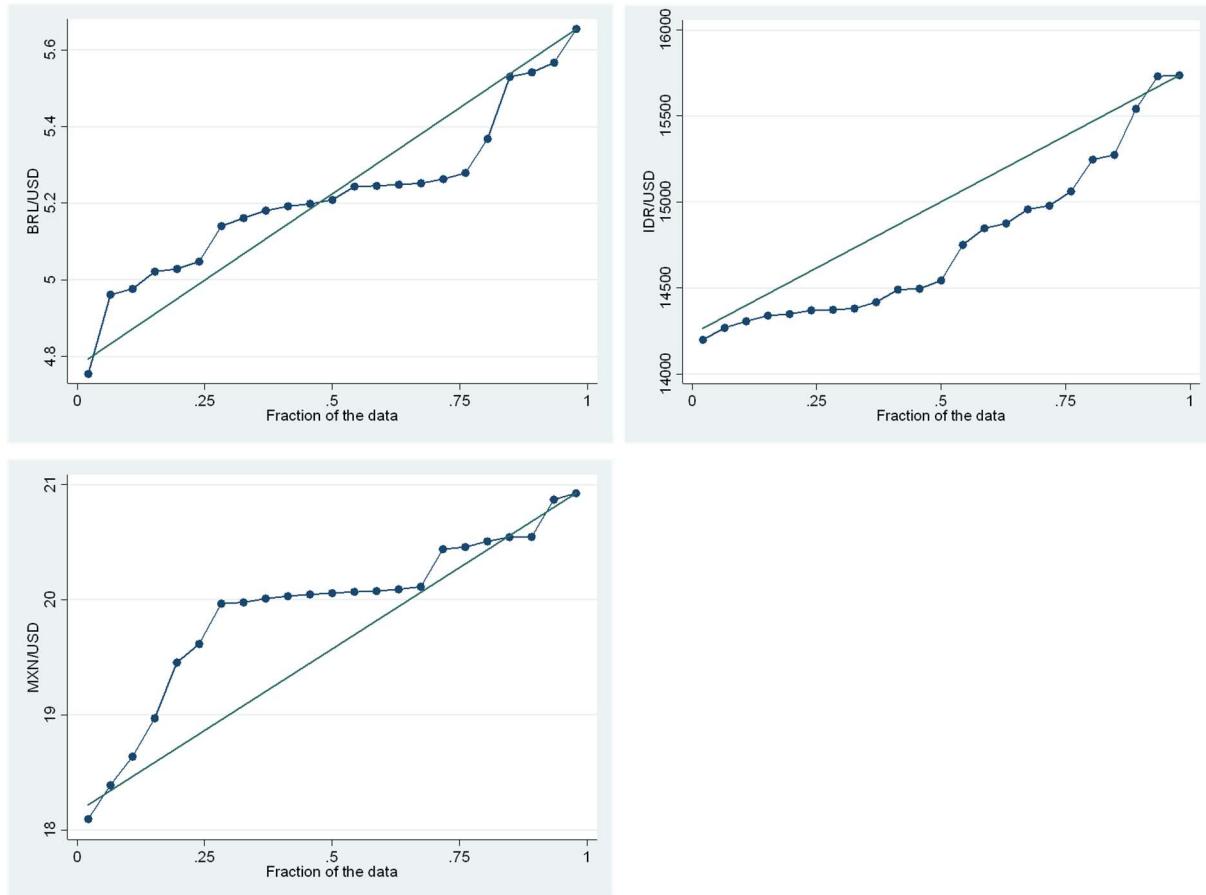




Quantile Plot of Various Currencies exchange rate wrt USD over Jun '21 to Apr'23







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