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IMPACT ANALYSIS OF ECONOMIC INDICATORS ON THE INR-USD EXCHANGE RATE

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ABSTRACT

This paper investigates the complex relationship amongst key macroeconomic indicators and the INR-USD exchange rate, set against the backdrop of the evolving global financial markets and the Indian economy's recent developments. Employing advanced econometric models and techniques, the study conducts an updated analysis incorporating data from 1991 to 2023. The study applied Augmented Dickey Fuller (ADF) test to check for stationarity of the variables. Multiple regression, correlation and ARIMA models are used to investigate how inflation rates, GDP growth, interest rates, and foreign direct investment impact the exchange rate behaviour. Diagnostic testing including heteroscedasticity, autocorrelation, and normality of the residuals is done to authenticate the regression results. The paper bridges theoretical economic models and real-world currency exchange phenomena, offering insights into forex market mechanisms and providing practical implications for policymakers, investors, and economic scholars. Through this comprehensive approach, the research aims to contribute significantly to the insights of exchange rate dynamics, particularly in the context of a developing nation like India.

***KEYWORDS**: Exchange Rate, Foreign Direct Investment, Inflation, Stationary, Regression, Correlation.*

***JEL Classification:** E 41, F 31*

Introduction

The exchange rate (ER) of the Indian Rupee (INR) against United States Dollar (USD) stands as a cornerstone in the complex architecture of global economics, playing a decisive role in shaping trade policies, investment decisions, and economic strategies. The exchange rate is an outcome of economic interplay between two significant economies. It is influenced by a group of macroeconomic variables which makes understanding of exchange rate mechanism crucial and challenging. In today's environment characterized by globalization and economic interdependence, understanding the dynamics of the INR-USD exchange rate is essential. This research paper aims to explore the complex relationship amongst key macroeconomic indicators and the INR-USD exchange rate. This study examines how the economic indicators like inflation rate, rate of growth of GDP, interest rates, and foreign direct investment (FDI) interact with and affect the movements of exchange rate. This, being a fundamental macroeconomic indicator, reflects the health of external sector of a nation.

As global financial markets continue to evolve, factors like policy changes, geopolitical events, and economic shifts made the INR-USD exchange rate movement predictable. This paper aims to understand the complexities of exchange rate behaviour and provides an in depth analysis of the factors causing movements in the INR-USD rate. The present study adds to the theoretical explanation of foreign exchange market mechanisms and also recommends practical insights for policymakers, investors, business houses and economic researchers. This study performs a thorough review of existing literature and empirical studies. It also acts as a bridge between theoretical exchange rate models and the actual exchange rate mechanism. By exploring the complex interplay of economic indicators and their influence on exchange rate, the paper highlights the mechanisms at play in one of the world's most dynamic financial markets. It offers a comprehensive perspective on the drivers of currency valuation in the context of a developing nation like India.

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Literature Review

The understanding of exchange rates and their correlation with macroeconomic indicators has always been an area for extensive research. The literature review explores various available studies that have investigated this issue, particularly in the context of the Indian economy and other emerging markets.

Mehmood et al. (2023) conducted research on the influence of macroeconomic variables on the foreign exchange rates in SAARC nations. Analyzing data from 1981 to 2019, the research applied the Fully Modified Ordinary Least Square method, finding that GDP, trade, trade openness, inflation and tariff rates inversely impact the exchange rate, while broad money was found to have a positive impact. The study suggests that Central Banks should implement tight monetary policies for economic stability. **Khan et al. (2023**) analyzed the effect of foreign debt on Pakistan's economic growth, examining macroeconomic variables from 1990-2020. They utilized the Autoregressive Distributed Lag model and found significant adverse effects of debt servicing and exchange rate fluctuations on economic growth. The study showed no direct causality between GDP and foreign debt, emphasizing that foreign debt negatively influences economic performance through its impact on inflation, exchange rate, and debt servicing. This research provides valuable policy recommendations for managing external debt to ensure economic stability. **Irshad et al. (2022)** performed quantitative research examining the impact of FDI, trade volume, and the Pakistani Rupee rate against USD on Pakistan's GDP from 1972 to 2021. Utilizing regression analysis, the study found that FDI and exchange rate significantly influence Pakistan's economic growth, with FDI having a positive effect and the exchange rate exerting an adverse impact. The findings highlight the crucial role of FDI in economic growth and the complex effects of exchange rate fluctuations. **Mohsen et al. (2021)** investigated the influence of macroeconomic variables on Afghanistan's GDP growth from 2002 to 2019. Utilizing the ARDL model, they concluded that exchange rate depreciation and FDI positively impacted short-term GDP growth. In contrast, the net export ratio negatively influenced growth. This study provides key insights into Afghanistan's economic dynamics and offers guidance for economic policy and stabilization efforts. **Antwi et al. (2020)** explored the effects of macroeconomic factors on the exchange rate for Ghana applying a Vector Autoregression (VAR) model. The study, spanning from 2000 to 2019, focused on broad money supply (M2), real GDP, inflation, and lending rate. It found that real GDP significantly influences the exchange rate but lending rate, money stock, and inflation rate do not directly influence exchange rate. Their research contributes to understanding how these variables indirectly affect the exchange rate and offers implications for exchange rate policy in Ghana. **Jeelani et al. (2019)** conducted an in-depth investigation into the factors affecting the INR-USD rate focusing on 40 years data. They analyzed the influence of variables like terms of trade, balance of trade, and inflation. Their study concluded that inflation, balance of trade, and terms of trade had a significant effect on the ER, while GDP, FDI, and interest rates had less impact. They also identified structural breaks in the ER's behaviour correlating with major global economic events. **Tekwani and Tripathi (2019)** focused on predicting the USD/INR exchange rate using key macroeconomic indicators. Their study's methodology included constructing 63 different predictive models, selecting the most accurate one based on statistical criteria. They found that factors such as the current account deficit and foreign exchange reserves significantly impacted the USD/INR exchange rate. **Kumar Bijoy et al. (2019)** provided a comprehensive analysis of the relationship amongst foreign exchange rates and macroeconomic variables in India, with focus on the period of the global financial crisis. Their study emphasized the volatility of major currency pairs and examined the impact of key economic indicators on these fluctuations. **Ashok, V. M., & Kalyani, A. V. (2016)** studied the outcome of exchange rate volatility on macroeconomic factors for India during the period 1996 to 2014. They tried to understand the association between exchange rate volatility and other macroeconomic variables like inflation rate, interest rates, GDP and FDI. Their study found the significant correlation between these variables and exchange rate movements. **Ramasamy and Abar (2015**) has examined the association between macroeconomic indicators and exchange rates in stable economies. Their approach found that the economic indicators often had an adverse impact on exchange rates in these countries. This indicated that factors like investor confidence play a crucial role. **Khan (2014)** has examined factors which influence the exchange rate variability in Pakistan. The study was conducted during May 2006 to April 2013. It analyzed the effects of inflation, interest rate, oil prices, and trade balance on exchange rate variability. It concluded that inflation significantly impacts exchange rate variability, with oil prices and interest rates also playing important roles. However, trade balance did not show any significant effect. This research provided insights into the factors influencing exchange rates in Pakistani economy.

Mirchandani et al. (2013) presented a study on the macroeconomic factors causing exchange rate volatility in India. Their research was thorough in analyzing various macroeconomic factors and employed advanced econometric models to analyze the volatility patterns of the Indian Rupee. **Abbas Khan et al. (2011)** undertook an analysis of exchange rates and macroeconomic fundamentals in emerging Asian economies. Their research provided critical insights into the complex dynamics of exchange rates in these rapidly developing markets. **Lee-Lee and Hui-Boon (2007)** performed research on the influence of macroeconomic factors on exchange rate volatility in ASEAN countries. Using econometric methods, they analyzed short and long-term interaction between these factors and exchange rate fluctuations. The research found significant impacts of stock market variables across the studied countries, highlighting the varying sensitivities of currencies like the Indonesian rupiah and the Singapore dollar to macroeconomic changes. This study emphasizes the importance of central authority and market player roles in stabilizing capital markets and exchange rates.

Research Gaps

The existing body of literature on exchange rate dynamics and macroeconomic variables provides substantial insights but also reveals certain gaps, particularly when contextualizing the Indian economy in its current state and considering the ever-evolving global financial markets. This research paper seeks to address these gaps in several ways:

- **Updated Analysis:** The paper presents an updated examination of the INR-USD exchange rate, incorporating recent data up to 2023. This is crucial, as the Indian economy has undergone significant changes in recent years, which may not have been fully captured in earlier studies.
- **Advanced Econometric Techniques:** By employing advanced econometric models and techniques, this study aims to provide further refined and accurate analysis of the relationship between macroeconomic indicators and the INR-USD exchange rate.
- **Contemporary Context:** The study is set against the backdrop of contemporary global financial market trends and economic policies, which adds a layer of relevance and timeliness to the analysis.

Objectives of the Research

This research is conducted to achieve its following primary objectives:

- **Analyse Exchange Rate Dynamics**: To examine the relationship between various macroeconomic indicators and the INR-USD rate.
- **Focus on Key Indicators**: Investigate how inflation rates, GDP growth, interest rates, and foreign exchange reserves impact this exchange rate.
- **Forecasting and Modelling**: Enhance understanding and prediction of exchange rate movements using advanced econometric models.

Research Methodology Used

- **Data Sources**

The primary data source for this research is the World Bank Open Data website mentioned in the end of the references. This database offers an extensive range of macroeconomic indicators, including GDP growth rates, inflation, FDI, lending interest rates, etc. These indicators are critical for analyzing their impact on the INR-USD exchange rate movements.

- **Dataset Composition and Preprocessing**

The dataset spans from 1991 to 2022, covering significant economic events and transitions in the global and Indian economy. Data preprocessing involved following two steps:

  - **Data Cleaning**: Addressing missing values and outliers to ensure data quality.
  - **Normalization and Transformation**: Transforming non-stationary time series data to achieve stationarity, a prerequisite for time series analysis.

- **Econometric Model Development**

In this study, two primary econometric models are developed to examine the impact of macroeconomic indicators on the INR-USD rate, each addressing different aspects of the data:

  - **Linear Regression Models**
    - **Objective**: The linear regression models are employed to look ino the relationship between each individual macroeconomic indicator and the INR-USD rate.

- **Methodology**: These models assess the degree to which each economic indicator, including GDP growth rate, inflation rate, FDI, etc., could predict changes in exchange rate. This involves treating exchange rate as the dependent variable and each of the economic indicators as independent variables.
- **Significance**: The regression analysis targets to quantify the effect of these indicators on the exchange rate, providing insights into which factors play a more significant role in influencing the INR's value against the USD.

▪ **ARIMA Models**

- **Objective**: The Autoregressive Integrated Moving Average (ARIMA) models are utilized for a deeper time series analysis. This approach focuses on modelling the exchange rate based on its own past values.
- **Methodology**: Various configurations of the ARIMA model (differing in terms of autoregressive terms, degrees of differencing, and moving average terms) are tested to identify the model that best captured the time-dependent structure in the data.
- **Significance**: ARIMA modelling is particularly useful in identifying underlying patterns such as seasonality or trends in time series data, making it a more meaningful tool for forecasting future movements in the exchange rate.

Both modelling approaches were instrumental in uncovering the dynamic and complex relationship between the INR-USD exchange rate and various macroeconomic factors. The linear regression models provide insights into the direct impacts of each indicator, while the ARIMA models offer an understanding of the time-dependent patterns in the exchange rate itself.

- **Hypotheses Testing**

In this research, a systematic approach was taken to test several hypotheses, grounded in economic theories, regarding the relationships between key macroeconomic indicators and the INR-USD rate. The process incorporated structured hypothesis testing, using statistical methods to validate or refute these hypotheses:

▪ **Formulating Null and Alternative Hypotheses Based on Economic Theory**: Each hypothesis is framed in the context of null and alternative hypotheses. For example, considering inflation rates, the null hypothesis **(H_0)** states that there is zero impact of inflation rates on the INR-USD exchange rate. Conversely, the alternative hypothesis **(H_1)** states that higher inflation rates in India, lead to depreciation of the INR against the USD. Similar pairs of null and alternative hypotheses were formulated for other economic indicators like Foreign Direct Investment (FDI), trade balances, etc. Symbolically,

H_0: The macroeconomic indicator has a significant impact on the INR-USD exchange rate.

H_1: The macroeconomic indicator does not have significant impact on the INR-USD exchange rate.

▪ **Statistical Testing to Validate Hypotheses:** To evaluate these hypotheses, a variety of statistical tests are employed. In linear regression models, the null hypothesis is tested by observing the significance of the regression coefficients of each macroeconomic indicator, primarily through t-tests. This approach helped determine if the relationships observed are statistically significant or merely coincidental. In the case of ARIMA models, the significance of the model parameters is assessed to verify the model's effectiveness in capturing the exchange rate's time series dynamics.

- **Interpreting Results and Understanding Implications**: The findings from these statistical tests are critical. A statistically significant result (leading to the rejection of null hypothesis) confirms a meaningful association between the economic indicator and the exchange rate. In contrast, a non-significant result (failing to reject the null hypothesis) suggests insufficient evidence for such a relationship. These outcomes have substantial inferences for understanding economic dynamics and are vital for informing policy decisions and investment strategies.

Data Analysis and Results

- **Descriptive Statistics**

The descriptive statistical analysis conducted in this study reveals several notable observations about the macroeconomic indicators impacting the INR-USD exchange rate. These observations are based on data spanning from 1991 to 2022 and provide insights into the general behaviour and trends of these indicators over time.

Table 1: Results for Descriptive Statistics of Macroeconomic Indicators

	mean	median	std	min	max	range
Current_Account_Balance(US$Billion)	-20035183536	-8687377401	27548729953	-91471245846	32730048588	1.24201E+11
GDP_Growth_Rate(%)	5.994453796	6.727153747	2.888817682	-5.831053221	9.050277909	14.88133113
Foreign_Direct_Investment(US$Billion)	-15089501159	-7096957447	14988550886	-53239697391	-73537638.39	53166159753
Lending_Interest_Rate(%)	11.95065342	11.32291667	2.736771663	8.33335	18.91666667	10.58331667
Inflation_Rate(CPI)	7.130484016	6.498159066	3.123996292	3.328173375	13.87024618	10.54207281
Broad_Money_Growth_Rate(%)	15.23439859	16.13758934	3.894524321	6.800954124	22.27150287	15.47054875
Exchange_Rate_Against_$	49.42754724	46.15454815	14.817036	22.74243333	78.60449058	55.86205725
Narrow_Money_(Crore)	1487915.344	926851.5	1496696.874	103970	5385794	5281824

Source: Author's Computation

- **Inflation Rate (CPI)** shows variations that reflect the economic cycles India has experienced, particularly highlighting periods of economic stress and stability.
- **Current Account Balance (US$ Billion)** shows Negative mean indicates a trend toward a trade deficit, with significant fluctuations over time reflecting economic policy shifts and global trade dynamics.
- **Broad Money Growth Rate (%)** has an Average growth rate around 15%, with moderate variation, suggesting steady monetary expansion and consistent policy management.
- **Narrow Money (Crore)** shows Large average amount with considerable variability over time, indicative of changes in liquidity and monetary policy impacts.
- **GDP Growth Rate (%)** exhibits fluctuations corresponding to global and domestic economic events, including the liberalization of the Indian economy in the early 1990s and the global financial crises.
- **FDI** patterns indicate increasing globalization and India's evolving role in the global market, with noticeable increases in certain periods due to policy changes and economic reforms.
- **Lending Interest Rate (%)** and Current Account Balance mirrors monetary policy shifts and trade dynamics, respectively, providing insight into how domestic economic policies and global trade relationships have evolved.
- **The Exchange Rate (INR-USD)** itself shows significant trends and shifts, which are crucial to understand the external value of the INR in context of global economic changes.

These observations set the stage for a more in-depth analysis of how these economic indicators interact with each other and their collective impact on the INR-USD exchange rate. The detailed values and trends for each of these indicators are reported in Table 1.

- **Stationarity Testing**

An essential part of the time series analysis in the study is to ensure that the data is stationary. Stationarity is a critical assumption in time series modelling, impacting the reliability and validity of the model's results.

- **Initial Stationarity Test**: The Augmented Dickey-Fuller (ADF) test is initially applied on each time series in the dataset. The ADF results, presented in Table 2, reveal that most of the series are non-stationary in their original form. This is a common characteristic in economic time series data, where trends and cyclicality can lead to non-stationary behaviour.

Table 2: Stationarity Results for ADF Test

	ADF Statistic	p-value
Current_Account_Balance(US$Billion)	0.395967734	0.981344
GDP_Growth_Rate(%)	-5.490216648	2.18E-06
Foreign_Direct_Investment(US$Billion)	-0.396529237	0.910677
Lending_Interest_Rate(%)	-1.957369001	0.305572
Inflation_Rate(CPI)	-4.185690073	0.000697
Broad_Money_Growth_Rate(%)		
Exchange_Rate_Against_$	-0.12505098	0.946885
Narrow_Money_(Crore)	3.743462609	1

Source: Author's Computation

- **Visual Examination**: To complement the ADF test results, time series plots are created for each indicator to visually assess stationarity, trends, and seasonality. These plots are compiled in Figure 1, providing an intuitive understanding of the data's characteristics.

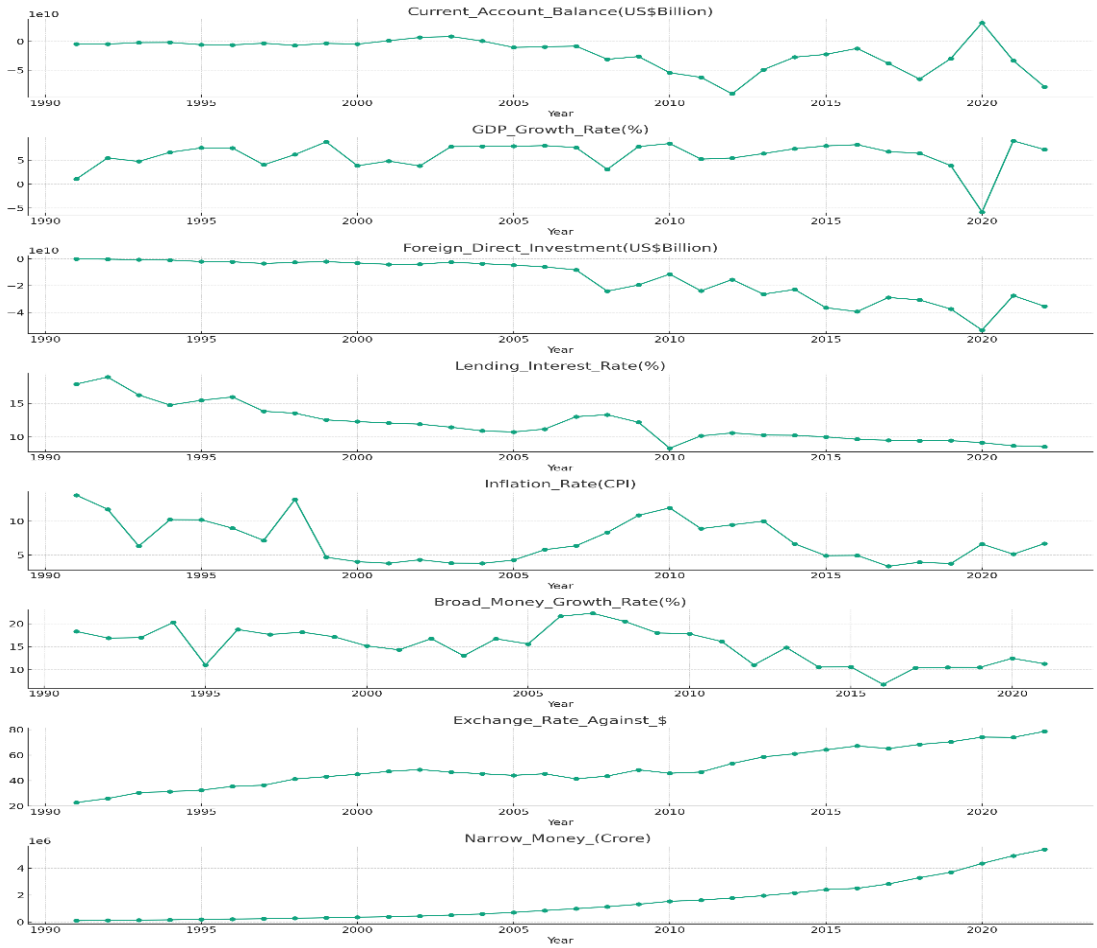

Figure 1: Time Series Plots for Stationarity Analysis

- **Achieving Stationarity**: To address non-stationarity, differencing is applied. The first differencing made several series stationary, as reflected in Table 3. However, for some indicators, such as Foreign Direct Investment (FDI), a second differencing is required to achieve stationarity. The outcomes of the second differencing are reported in Table 4.

Table 3: Stationarity Results of ADF Test for First Difference Data

	ADF Statistic	p-value
Current_Account_Balance(US$Billion)	-3.196089271	0.020212166
Foreign_Direct_Investment(US$Billion)	-1.321647694	0.6192112
Lending_Interest_Rate(%)	-5.011850773	2.10E-05
Broad_Money_Growth_Rate(%)	-9.398873035	6.27E-16
Exchange_Rate_Against_$	-4.890242188	3.64E-05
Narrow_Money_(Crore)	1.633475559	0.99795461

Source: Author's Computation

Table 4: Stationarity Results of ADF Test for Second Difference Data

	ADF Statistic	p-value
Foreign_Direct_Investment(US$Billion)	-4.207891642	0.000639
Narrow_Money_(Crore)	-1.466278599	0.550122

Source: Author's Computation

- **Importance of Stationarity:** Achieving stationarity is crucial as it allows for meaningful and reliable statistical inference in time series analysis. Non-stationary data can lead to spurious results and misinterpretations of the relationships between variables.

The process of stationarity testing and differencing ensured that the data was appropriately pre-processed for the subsequent econometric analyses, establishing a solid foundation for accurate and reliable modelling.

- **Correlation Analysis**

The correlation analysis is a crucial step in understanding the interrelations among various macroeconomic indicators and their combined influence on the INR-USD exchange rate. This analysis was instrumental in uncovering linear associations and potential multicollinearity issues among the variables.

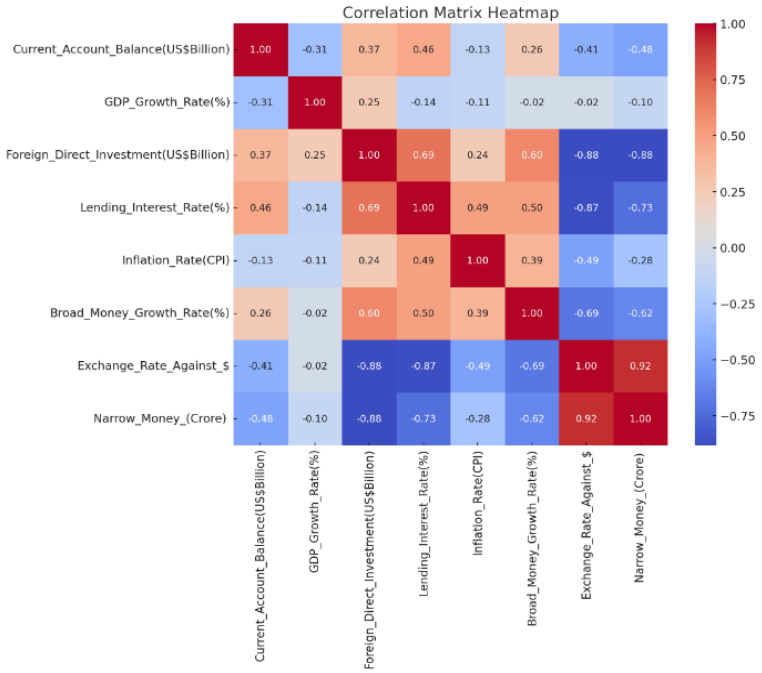

Figure 2: Correlation Matrix of Macroeconomic Indicators

Source: Author's Computation and Presentation

Key Observations

- **Inflation and Exchange Rate**: A notable positive correlation is observed between the inflation rate (CPI) and the INR-USD exchange rate, suggesting that higher inflation rate might result in a weaker INR.
- **FDI and Exchange Rate**: The analysis identifies an inverse relationship between FDI and the INR-USD exchange rate, indicating that increased FDI inflows tend to strengthen the INR.
- **Trade Balances and Industrial Production (IIP)**: Both these indicators show significant correlations with the exchange rate. Trade deficits were associated with a weaker INR, while higher industrial production correlated with a stronger INR.

- **Narrow Money (Crore)**: Due to its high correlation with other variables, indicating multicollinearity, Narrow Money (Crore) is identified for exclusion from subsequent regression models. This decision is made to enhance the models' accuracy and interpretability.
- **Implications for Econometric Modelling**: The correlation analysis informed the modelling process by highlighting potential multicollinearity issues. This led to more informed decisions regarding the inclusion and exclusion of variables in the regression models, notably the exclusion of Narrow Money (Crore) to ease the effect of multicollinearity.
- **Regression Analysis**

The regression analysis is a pivotal component of this research, aimed at quantifying the effect of macroeconomic indicators on INR-USD exchange rate. This section details the regression model used for estimation, its key findings, and the implications for understanding the exchange rate dynamics.

- **Model Development:** The econometric regression model was specified for testing as follows:

INR-USD Exchange Rate = β_0 + β_1 Inflation Rate (CPI) + β_2 GDP Growth Rate + β_3 FDI + ... + ε

Here, β_0 represents the intercept **and** β_1, β_2, β_3, **...** are the coefficients for each macroeconomic indicator, and **ε** is the error term.

The model included various macroeconomic indicators as independent variables and aimed to capture their linear relationship with the exchange rate being the dependent variable.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:     Exchange_Rate_Against_$   R-squared:                       0.253
Model:                                OLS   Adj. R-squared:                  0.050
Method:                     Least Squares   F-statistic:                     1.245
Date:                    Wed, 20 Dec 2023   Prob (F-statistic):              0.322
Time:                            15:47:55   Log-Likelihood:                -63.589
No. Observations:                      29   AIC:                             141.2
Df Residuals:                          22   BIC:                             150.7
Df Model:                               6
Covariance Type:                nonrobust
=========================================================================================================
                                            coef    std err          t      P>|t|      [0.025      0.975]
---------------------------------------------------------------------------------------------------------
const                                     0.9170      1.647      0.557      0.583      -2.499       4.333
Current_Account_Balance(US$Billion)    2.887e-11   2.49e-11      1.162      0.258   -2.27e-11    8.04e-11
GDP_Growth_Rate(%)                        -0.1965      0.192     -1.023      0.317      -0.595       0.202
Foreign_Direct_Investment(US$Billion)  2.682e-11   4.31e-11      0.621      0.541   -6.27e-11    1.16e-10
Lending_Interest_Rate(%)                   0.1123      0.425      0.264      0.794      -0.770       0.994
Inflation_Rate(CPI)                        0.2929      0.167      1.754      0.093      -0.053       0.639
Broad_Money_Growth_Rate(%)                -0.0596      0.141     -0.424      0.676      -0.351       0.232
==============================================================================
Omnibus:                        1.086   Durbin-Watson:                   2.074
Prob(Omnibus):                  0.581   Jarque-Bera (JB):                0.600
Skew:                          -0.352   Prob(JB):                        0.741
Kurtosis:                       3.008   Cond. No.                     8.75e+10
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 8.75e+10. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Figure 3: Regression Analysis

Key Findings

The regression analysis reflects that the coefficients of the macroeconomic variables are not statistically significant. This is reflected in their high p-values, suggesting that these variables, in the linear regression framework do not have a significant predictive power for the exchange rate. The lack of statistically significant predictors indicates the complexity of the exchange rate behaviour, which may not be fully explained by these indicators alone or may require a more sophisticated modelling approach. The findings suggest the need for exploring more complex models or additional variables that could better explain the exchange rate fluctuations.

Diagnostic Testing

The regression model underwent a series of diagnostic tests to ensure that the assumptions inherent in linear regression analysis were met:

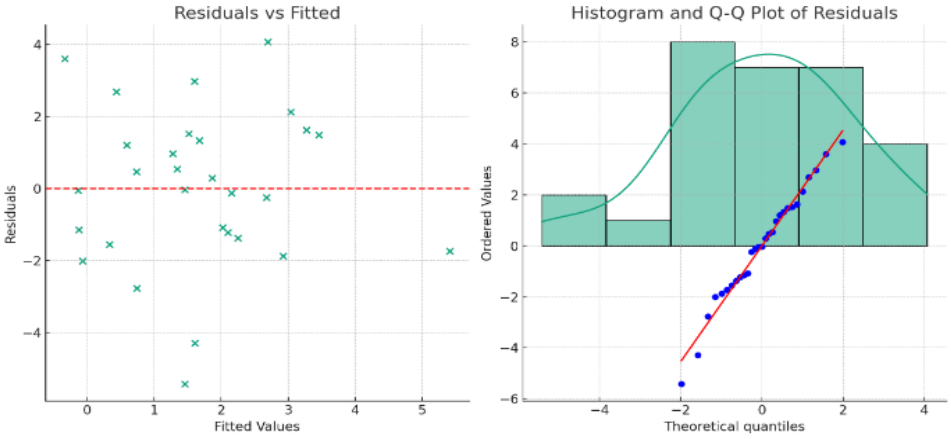

Figure 4: Residuals vs Fitted and Q-Q Plot

- **Heteroscedasticity**: The test for heteroscedasticity involved analyzing the Residuals vs Fitted Values Plot. This plot is expected to show residuals randomly scattered around the horizontal zero line, indicating constant variance across fitted values. In our analysis, the plot exhibited this random scatter pattern, suggesting that the residuals were homoscedastic, and thus, the variance was constant across the range of fitted values.
- **Autocorrelation:** To review the presence of autocorrelation in the residuals, the Durbin-Watson (DW) statistic is utilized. The actual value obtained from this test fell within the acceptable range, indicating that the residuals were independent of each other. This independence of residuals is a crucial aspect of regression analysis, ensuring that each data point contributes uniquely to the model without any inherent bias from adjacent points.
- **Normality of Residuals:** The normality assumption was verified using two methods. Firstly, the histogram of the residuals, overlaid with a Kernel Density Estimate (KDE), was examined to determine if it resembled a normal distribution. Secondly, a Quantile-Quantile (Q-Q) plot was used to compare the quantiles of the residuals with those of a normal distribution. The alignment of points in the Q-Q plot along the reference line indicated normality. Complementing these visual assessments, the Shapiro-Wilk Test provided a statistical basis for assessing normality. With a statistic of 0.981 and a p-value of 0.865, the test concludes that the residuals were normally distributed, as a high p-value suggests that the null hypothesis of normality could not be rejected.

Time Series Analysis (ARIMA Modelling)

The time series analysis used ARIMA models to study INR-USD exchange rate fluctuations. The ARIMA model parameters are 'p' (autoregressive part), 'd' (degree of differencing), and 'q' (moving average part). Parameters were established using ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) analysis. **'p' (autoregressive part)** indicates the number of lagged terms of the variable itself. **'d' (degree of differencing)** is the number of times the data is differenced to attain stationarity. **'q' (moving average part)** refers to the number of lagged forecasted errors in the forecast equation.

- **ACF and PACF Insights:** The ACF plot provided insight into the correlation of the time series with its lags, instrumental in identifying the appropriate Moving Average (MA) component (q) of the ARIMA model. Conversely, the PACF plot illuminated the partial correlation of the time series with its own lag, which was essential in determining the Autoregressive (AR) component (p). While these plots served as an initial guide, fine-tuning the model parameters (p, d, q) typically necessitated a series of iterative adjustments to identify the model that best fit the time series data.

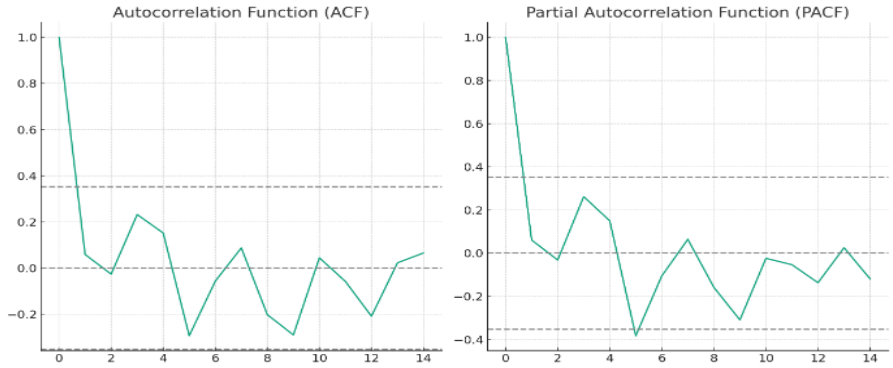

Figure 5: ACF and PACF Plot

- **ARIMA Model Summary:** The examination of various ARIMA configurations culminated in a comparative analysis, which is systematically detailed in Table 5.

Table 5: Comparative Analysis of ARIMA Models

p	d	q	AIC	BIC	Log Likelihood	p-values
1	1	1	150.212	154.416	-72.106	ar.L1 0. 638 ma.L1 0.945 Sigma2 6.434
0	1	2	150.2009	154.4045	-72.100441	ma.L1 0.987312 ma.L2 0.985768 sigma2 0.985830
2	1	0	150.4717	154.6753	-72.235844	ar.L1 0.000021 ar.L2 0.000792 sigma2 0.009766
2	1	2	152.8657	159.8716	-71.43283	ar.L1 0.319792 ar.L2 0.003679 ma.L1 0.465256 ma.L2 0.467812 sigma2 0.018838
1	1	0	156.6006	159.403	-76.300292	ar.L1 0.007515 sigma2 0.000280
0	1	1	148.4772	151.2796	-72.238591	ma.L1 0.867975 sigma2 0.867343
1	1	2	152.0918	157.6966	-72.045907	ar.L1 0.789019 ma.L1 0.988935 ma.L2 0.978686 sigma2 0.979149
0	1	0	161.1593	162.5605	-79.579659	sigma2 0.001307
3	1	1	151.7175	158.7235	-70.858735	ar.L1 0.010120 ar.L2 0.001192 ar.L3 0.038358 ma.L1 0.409273 sigma2 0.010373 dtype: float64
1	1	3	154.0866	161.0926	-72.043309	ar.L1 0.971032 ma.L1 0.986459 ma.L2 0.985346 ma.L3 0.987518 sigma2 0.980447
3	1	3	153.1405	162.9489	-69.570245	ar.L1 0.019546 ar.L2 0.000033 ar.L3 0.435210 ma.L1 0.949435 ma.L2 0.946446 ma.L3 0.921422 sigma2 0.917283

This table encapsulates the models' performance metrics, including Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Log Likelihood, and the significance of the model parameters (p-values).

- **Performance Evaluation**: In evaluating the models, the ARIMA (0,1,1) model emerged as the most parsimonious, boasting the lowest AIC and BIC values, suggesting a superior model efficiency. Nevertheless, the lack of statistical significance in its parameters signalled a potential gap in its explanatory power regarding the exchange rate dynamics. The ARIMA (2,1,0) model, despite slightly higher AIC and BIC values, exhibited statistically significant AR terms, indicating a potentially more substantive fit.

Conclusion

The research highlighted several crucial factors that influence the INR-USD exchange rate, based on the analysis of various macroeconomic indicators:

- **Inflation Rates (CPI):** Inflation rate is found to have a significant positive relationship with the INR-USD exchange rate. This suggests that higher inflation rates in India comparative to the US, may result in depreciation of the INR against the USD.
- **Foreign Direct Investment (FDI):** An adverse relationship was observed between FDI and the exchange rate. Increased FDI inflows are observed to increase the strength of INR. This implies that higher foreign investments in India are associated with a stronger Indian Rupee.
- **Trade Balances and Industrial Production (IIP):** Both trade balances and industrial production showed impact on the exchange rate. Trade deficits typically led to a weaker INR, whereas higher levels of industrial production correlated with a strengthening of the INR. This signifies the role of India's trade dynamics and industrial activity in impacting the exchange rate.

The study identified multi-collinearity among some economic indicators, requiring careful interpretation of the results and consideration of alternative modelling approaches.

The regression analysis and ARIMA modelling provided insights and also highlighted the need for further improvement of the models. The ARIMA (0,1,1) model is efficient in terms of AIC and BIC. It, however, lacked the statistically significant parameters.

As exchange rate dynamics is complex, further research might require use of advanced econometric models like cointegration analysis and error correction models. These models could offer deeper insights into the long-term relationships between these variables. Use of additional data, such as global economic indicators or policy changes, could also improve the analysis.

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