Research Article

Exchange Rate Dynamics and Recent Shocks in India

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ABSTRACT

Exchange rate stability in the economy is one of the most important determinants of its economic performance. This study highlights the role of several macroeconomic variables like trade balance, Foreign Direct Investment (FDI) inflows, foreign exchange reserves, interest rate differentials, and GDP growth differential and the influence of volatile events like the 2007-2008 global financial crisis, India's 2016 demonetization drive, and the COVID 19 pandemic on the Indian Rupee (INR) against the US Dollar (USD). The study employs annual time-series data for the 1979-2024 period based on the Federal Reserve Economic Data (FRED) Database and the World Bank and Ordinary Least Squares (OLS) regression model as a reference point with Autoregressive Distributed Lag (ARDL) and Error Correction Models (ECM) to study short-run dynamics and long-run equilibrium relationships. The INR/USD exchange rate is extremely reliant on trade balance, foreign exchange reserves, GDP growth differentials, and FDI flows, while interest rate differentials have a relatively weaker relationship. The study employs ECM and finds that exchange rate volatility due to events or shocks fails to revert to the level of equilibrium in time. Policymakers can benefit by the findings of this study since it quotes the determinants of the INR/USD exchange rate to enhance the economic resilience against future shocks.

Keywords: Exchange Rate; FDI Inflows; Trade Balance; GDP; Interest Rate; Forex reserves

INTRODUCTION

Exchange rates are critical due to their various impacts on trade performance, import inflation, external debt sustainability, financial markets, and overall economic growth. A sudden change in exchange rates causes discrepancies in the costs and revenues generated by imports and exports from a country. This adjusts demand and supply accordingly, leading to an imbalanced balance of payments for a country, and thus poorer trade performance. Stable exchange rates prevent surges in import prices, protecting consumers and businesses from inflationary pressures. They are also essential for external debt sustainability, as depreciation increases repayment burdens on foreign-denominated loans, straining public finances. Exchange rates affect financial markets by altering the value of foreign-denominated assets and returns. Financial markets thrive on stability, attracting foreign investment and maintaining liquidity. Unexpected changes in exchange rates can act as the cause for various economic events. A devaluation of currency may lead to lower imports and more exports, which increases trade tensions causing retaliatory tariffs and sparking trade wars. Persistent volatility in exchange rate causes declining

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confidence in the U.S. dollar's value could accelerate de-dollarization efforts as foreign countries seek alternative currencies for trade and reserves. Similarly, fluctuations in major currencies may push BRICS nations to reduce reliance on dominant currencies like the dollar, encouraging trade in local currencies and restructuring global supply chains.

Highly volatile events such as the Global Financial Crisis of 2007, demonetization in India, and the COVID-19 pandemic have triggered significant fluctuations in exchange rates, creating profound economic uncertainty. These shocks disrupt capital flows, trade balances, and investor confidence, leading to exchange rate instability that can exacerbate underlying macroeconomic vulnerabilities. The effects of such instability are often not short-lived; depending on the severity and nature of the event, it may take several quarters—or even years—for exchange rates to stabilize and return to pre-shock equilibrium levels. In many cases, there is a lagged effect, where the full impact on exchange rates is not immediately visible. For instance, during the COVID-19 pandemic, initial volatility was driven by capital outflows and uncertainty, but deeper effects emerged only later as global trade contracted and monetary responses diverged across economies. Following a major shock, currency markets typically experience heightened volatility, reduced liquidity, and speculative pressures. This can force central banks to intervene, either directly through forex reserves or indirectly through monetary policy tools, further distorting natural exchange rate movements. Additionally, post-event recovery is often asymmetric — while some sectors or capital inflows rebound quickly, others lag, leaving the exchange rate in a state of flux for an extended period. Structural shifts, such as changes in global supply chains or long-term investor risk perceptions, may permanently alter exchange rate dynamics.

LITERATURE REVIEW

Theoretical Review

Exchange rate stability has been widely studied, with key influences identified as trade balance (1), interest rate differentials (2), forex purchases & sales, and GDP growth differentials between India and the US (3). These perspectives provide the foundation for analyzing how macroeconomic variables and shocks interact to affect the INR/USD exchange rate.

The Monetary Models of Exchange Rates emphasize the role of money supply and inflation. The flexible-price model (4) assumes rapid price adjustment, so monetary expansion causes depreciation, while the sticky-price model (5) explains short-term misalignments between exchange rates and fundamentals.

Both highlight inflation and output growth as drivers of currency movements, linking directly to GDP growth differentials and macroeconomic policy.

Purchasing Power Parity (PPP) theory (6) posits that exchange rates reflect relative price levels, with high inflation leading to depreciation (7). Deviations from PPP affect competitiveness and trade balances (8), making the theory relevant for India where inflationary shocks often spill into INR/USD volatility. The Balance of Payments (BOP) theory (9) similarly suggests that persistent trade deficits increase demand for foreign currency, depreciating the Rupee. Extensions such as the Elasticity and Absorption Approaches (10) emphasize how price elasticities and income shifts affect trade flows, reinforcing their importance for understanding how global and domestic shocks shape India's exchange rate.

The Interest Rate Parity (IRP) theory (11) suggests that differences in nominal interest rates between two countries are offset by expected changes in exchange rates. This theory directly relates to interest rate differentials, implying that higher domestic interest rates attract foreign capital (12), appreciating the domestic currency, and vice versa.

The Asset Market Approach (13) brings in the role of market expectations and speculative behavior. It suggests that exchange rates are forward-looking and reflect investors' expectations about future economic conditions, interest rates, and policy decisions. This approach integrates psychological and speculative factors, demonstrating how market sentiment and time trends can drive exchange rate fluctuations, often beyond what fundamentals would suggest. Another approach, called the Portfolio Balance Approach (14) improves on the stock equilibrium approach (15) and the BOP theory, emphasizing the influence of financial assets. According to this theory, investors balance their portfolios between domestic and foreign assets , and shifts in preferences can impact exchange rates. Central bank interventions, through the buying or selling or foreign currencies, can alter the supply and demand for domestic assets.

Volatile events such as the 07-08 Global Financial Crisis also have a significant impact on the exchange rate. The Exchange Rate Overshooting Model (5)

explains how volatile events like unexpected changes in monetary policy or economic crises can lead to extreme yet short-term movements in exchange rates. The theory emphasizes how slow price adjustments and rapid capital flows create temporary misalignments, which gradually stabilize as the economy adjusts.

Empirical Review

Empirical studies consistently show that exchange rates are shaped by both macroeconomic fundamentals and external shocks. While global evidence highlights trade, capital flows, and policy interventions as major determinants, India-specific studies provide important insights into how these mechanisms operate under conditions of volatility.

Exchange rates and trade balances have a significant interrelation (16). Research demonstrates that, under the Marshall–Lerner condition, depreciation can improve the trade balance by boosting export competitiveness (17), and depreciation has been observed to enhance exports and the trade surplus (18). At the same time, volatility can disrupt pricing and dampen both exports and imports, as shown in Brazil (19). Together, these findings capture the dual role of exchange rates in both competitiveness and trade stability in the Indian context.

Central banks frequently intervene to manage exchange rate fluctuations during volatile periods. Evidence from India indicates that RBI actions during the Global Financial Crisis helped stabilize INR/USD (20), and during COVID-19 similar interventions reduced excessive volatility in emerging markets (21). U.S. evidence suggests such interventions often have short-term effects with mixed long-run impact (22). This mixed record motivates testing whether India's reserves stabilize or destabilize INR/USD during shocks in our setting.

Interest rate differentials also matter, but effects vary by horizon and conditions. Indian evidence finds higher domestic rates can have a negative short-run effect but a positive long-run effect on the Rupee (23). In Turkey, volatility shocks can dominate these relationships in the short term before stabilizing later (24). This motivates examining the India–U.S. interest rate gap under both stable and crisis conditions.

Economic growth differentials influence currency behavior. Faster growth relative to a counterpart can attract investment inflows (25) and is often associated with currency appreciation (2), but in developing economies stronger growth can also raise import demand and increase foreign currency needs, producing depreciation pressure (26). This ambiguity is directly relevant for India and justifies including GDP growth gaps in our model.

Finally, shocks have pronounced and context-specific effects. During the Global Financial Crisis, many currencies depreciated while the U.S. dollar strengthened as a safe-haven currency (27, 28). COVID-19 generated volatility that rose with case counts, while government interventions helped contain instability (29). India's 2016 demonetization shows how a domestic policy shock can have different dynamics, with longer-term Rupee strengthening reported in the literature (30). These cases motivate our focus on both global and domestic shocks in explaining INR/USD dynamics.

METHODS AND MATERIALS

We employ annual time-series data from 1990 to 2024. The study employs a combination of baseline Ordinary Least Squares (OLS) regression and advanced econometric techniques for robustness checks. We retrieve data from various sources, including the RBI, the World Bank, the International Monetary Fund (IMF), and the Federal Reserve Economic Data (FRED).

The dependent variable for the study is the exchange rate between the Indian Rupee and the US Dollar. On the other hand, the independent variables, selected by the their relevance to exchange rates as discussed previously by the literature, include trade balance, central bank interventions, Net Foreign Direct Investment (FDI) Inflows, interest rate differential, GDP growth rate differential between India and the United States and a time trend to capture structural changes. Table 1 provides a detailed description of all variables, including their definitions, data sources, measurement units, and any transformations applied, to ensure clarity and replicability of the analysis.

We perform the OLS regression model, which serves as the baseline methodology for understanding the relationships between exchange rate stability and the selected independent variables. This linear regression framework is used for parameter estimation to understand the significance of each factor of exchange rates in the Indian context. This baseline method is particularly effective, However, it relies on several assumptions, including stationarity of the time-series data and absence of endogeneity, and it is

Table 1. Definitions, Data Sources, Units of Measurement, and Transformations of Macroeconomic Variables Incorporated into the Empirical Models of INR/USD Exchange Rate Dynamics

Variable	Definition	Source (s)	Units	Transformation
Exchange Rate (USD/INR)	Official market exchange rate between Indian Rupee and U.S. Dollar	RBI, FRED	INR per USD (annual avg)	Log transformation for stationarity tests
Trade Balance	Net exports (exports – imports) of goods and services	World Bank	Current USD (annual)	Converted to real terms where needed; scaled for regression
Foreign Exchange Reserves	Total official reserve assets held by RBI	RBI, IMF	USD (end of year)	Log transformation
Net FDI Inflows	Net Foreign Direct Investment inflows	RBI, World Bank	Current USD (annual)	Expressed as % of GDP; logged for stationarity
Interest Rate Differential	Difference between Indian and U.S. benchmark interest rates	RBI, FRED	Percentage points	Constructed as India – U.S.
GDP Growth Differential	Annual real GDP growth rate difference between India and the U.S.	World Bank, IMF	Percentage points	Constructed as India – U.S.

highly reliable in data with low scope of error. Time-series data, especially in economic contexts, often exhibit non-stationarity, which can lead to biased and inconsistent results if not addressed. Therefore, we can complement this method with various error-correction and robustness models.

We employ the Autoregressive Distributed Lag (ARDL) model, which is particularly well-suited for analyzing time-series data with mixed integration orders. The ARDL model allows for both stationary and non-stationary variables to be tested for. This is especially useful as our study includes both I(0) and I(1) variables, making this method highly flexible and useful for this analysis. The ARDL model can also be used to capture both short- and long-term relationships between variables, which allows one to understand specifically the nature of the effect of each variable considered on exchange rates. THis is especially useful in the case of volatile events as considered in our study. For instance, demonetization might exhibit immediate effects on exchange rate stability due to abrupt liquidity constraints, but could also have long term effects such as more compliance to tax laws, leading to overall increase in exchange rate stability due to expanded government revenue. The ARDL approach also incorporates the Bound Testing method to understand whether any long-term equilibrium relationships among variables are present in the relation.

The study further employs an Error Correction Model (ECM). The ECM is specifically designed to measure how quickly a disruption to a relation between two variables gets readjusted and the relation reverts back to its original stable state. Furthermore, it also captures that long term relationship that was populated with numerous disruptions from different short-term events. In our study, the disruptions caused by various volatile events like the Global Financial Crisis, for example, could be studied and it could be uncovered how quickly/ slowly the economy finally recovered from its effects.

RESULTS

Diagnostic Tests

The final econometric analysis incorporates stationarity testing, cointegration analysis, the ARDL model, and the ECM model to examine how macroeconomic indicators and major economic shocks influence the INR/USD exchange rate. Building on the previous results, we implemented the Augmented Dickey-Fuller (ADF) test to check for stationarity of each variable. The results of the stationary testing can be seen in Table 2, and the results of the cointegration analysis can be seen in Table 3.

The ADF test confirmed that all variables were stationary after first differencing, except for Interest Rate Differential, which was stationary in levels. Given this mixed order of integration (I(0) and I(1)), the ARDL model is found to be ideal for the given situation, and it can thus safely proceed with it. The

Johansen Cointegration Test revealed the presence of three cointegrating relationships, confirming a long-run equilibrium relationship between exchange rate stability and the macroeconomic indicators currently being considered. Since cointegration was established, an ECM was used to analyze short-run deviations from equilibrium.

Table 2. Stationarity Tests: Presents results checking whether the time-series data is stable over time or affected by trends and seasonality

Variables	P-value (at level)	P-value (at 1st difference)
Exchange Rate	0.9906	0.0000
Trade Balance	0.9928	0.0001
For-ex Reserves	0.9988	0.0001
Net Inflows FDI	0.3806	0.0000
Interest Rates	0.0002	N/A
GDP Growth Difference	0.0000	N/A

Table 3. Cointegration Tests: Examines whether long-run equilibrium relationships exist among the time-series variables

Trace Test				
Rank	Statistic	90% CV	95% CV	99% CV
Trace Stat 1	129.23	91.109	95.7542	104.964
Trace Stat 2	83.2201	65.8202	69.8189	77.8202
Trace Stat 3	48.6926	44.4929	47.8545	54.6815
Trace Stat 4	23.5069	27.0669	29.7961	35.4628
Trace Stat 5	6.6984	13.4294	15.4943	19.9349
Trace Stat 6	1.22591	2.7055	3.8415	6.6349
Max Eigenvalue Test				
Rank	Statistic	90% CV	95% CV	99% CV
Max Eigenvalue 1	46.01	37.2786	40.0763	45.8662
Max Eigenvalue 2	34.5275	31.2379	33.8777	39.3693
Max Eigenvalue 3	25.1856	25.1236	27.5858	32.7172
Max Eigenvalue 4	16.8085	18.8928	21.1314	25.865
Max Eigenvalue 5	5.4725	12.2971	14.2639	18.52
Max Eigenvalue 6	1.22591	2.7055	3.8415	6.6349

Preliminary Results

The initial OLS regression results provide valuable insights into the relationship between exchange rate levels and key macroeconomic indicators, as shown in Table 4. However, since this is a preliminary model, certain econometric concerns, particularly the lack of stationarity and cointegration testing, must be acknowledged before drawing definitive conclusions. The regression output indicates a moderate R-squared value of 0.793, suggesting that the independent variables explain approximately 79.3% of the variation in the exchange rate. While this indicates a reasonable fit, it is important to consider the possibility of overfitting or the presence of multicollinearity among the independent variables. Examining the p-values, we find that Foreign Exchange Reserves ($p = 0.000$) are highly significant, while Net Inflows of FDI ($p = 0.073$) are close to significance. Trade Balance ($p = 0.719$), Interest Rate Differential ($p = 0.097$), and GDP Growth Differential ($p = 0.707$) are statistically insignificant, suggesting that, based on this preliminary model, they do not have a strong effect on the exchange rate. The coefficient of Foreign Exchange Reserves is positive, indicating that an increase in reserves is associated with a higher USD/INR exchange rate (depreciation of the rupee). This contrasts with previous expectations that reserves might support currency appreciation. Net Inflows of FDI have a positive coefficient, suggesting that higher FDI inflows may contribute to rupee depreciation, though this relationship is not strongly

Table 4. Preliminary Effect of macroeconomic variables on the exchange rate: Shows the simple OLS observed relationships between key economic indicators and currency value movements

Variable	Coefficient	Std. Error	t	p-value
const	12.3049	5.157	2.386	0.022
Trade Balance	-2.549e-11	7.03e-11	-0.363	0.719
For-Ex Reserves	8.381e-11	1.6e-11	5.252	0.000
Net Inflows FDI	5.1624	2.806	1.840	0.073
Interest Rate	1.1623	0.684	1.699	0.097
GDP Growth Diff	0.2154	0.570	0.378	0.707
R-squared	0.793	F-statistic Prob		29.81
Adjusted R-squared	0.766	(F-statistic)		2.43e-12
Log likelihood	-165.80			

significant. Trade Balance has a negative coefficient, but its high p-value suggests an unclear relationship.

A major limitation of this preliminary model is the absence of stationarity and cointegration tests. Exchange rate time-series data often exhibit non-stationarity, meaning that their statistical properties (mean, variance, autocorrelation) change over time. If the dependent and independent variables are non-stationary but not cointegrated, the regression results could be spurious, meaning the relationships detected by OLS may not be valid. To address this, the ADF test should be conducted to check for stationarity. If variables are found to be non-stationary, first-differencing may be required to ensure a more reliable regression. Additionally, the Johansen Cointegration Test should be applied to determine whether a long-run equilibrium relationship exists among the variables. To refine the model and ensure robust findings, the following steps should be taken: Conduct stationarity tests (ADF test) and, if necessary, transform non-stationary variables using first or second differences. Cointegration tests (Johansen test) should also be performed. Overall, while the preliminary results suggest some meaningful relationships between exchange rates and key economic indicators, further econometric testing is required to validate these findings and ensure the model's reliability.

Final Results

The ARDL model, estimated with manually selected lag values of 2 for each variable, provided several key insights. From Table 5, we notice that exchange rate at the first lag, trade balance at the 0th lag, foreign exchange reserves at both the 0th and 1st lag, net foreign direct investment at the 1st and 2nd lag, as well as GDP growth differential at the second lag are all significant with $p < 0.05$. The exchange rate exhibited strong persistence, meaning past values significantly influenced future values. Trade balance had a positive and significant effect, indicating that an improved trade balance corresponds with INR depreciation in the short term. This suggests that rather than strengthening the Rupee, a higher trade balance is associated with an increased exchange rate (more INR per USD), which may be due to factors such as capital inflows leading to increased liquidity or heightened import demand. The fact that this result is immediate (lag 0) suggests that the market quickly factors trade balance changes into the exchange rate.

Foreign exchange reserves initially increased volatility, likely due to intervention strategies, but had a stabilizing effect after a lag, confirming that reserves may not inherently stabilize the Rupee but are instead used reactively. The short-term destabilizing effect (lag 0) suggests that central bank interventions may create initial uncertainty in currency markets. However, the lagged positive effect (lag 1) implies that after a period of adjustment, reserves may contribute to exchange rate stabilization, possibly through managed foreign exchange operations by the RBI.

FDI inflows had a short-term strengthening effect on the Rupee at lag 1, suggesting that initial inflows create demand for INR, leading to appreciation. However, this impact reversed in the long run (lag 2), likely due to capital outflows as foreign investors repatriated profits or withdrew investments. The fact that this reversal occurs after two periods suggests that while FDI inflows provide short-term stability, their longer-term effects depend on investor retention and reinvestment behavior.

Interestingly, the GDP growth differential between

Table 5. Real Effect of macroeconomic variables on the exchange rate: Summarizes the actual long-term impact of economic indicators on currency movements

Variable	Coef.	Std. Err.	z	P>|z|
const	5.5355	1.764	3.138	0.004
Exchange Rate Lag 1	1.0446	0.169	6.185	0
Exchange Rate Lag 2	-0.0005	0.177	-0.003	0.998
Trade Balance Lag 0	5.88E-11	2.64E-11	2.226	0.035
Trade Balance Lag 1	-4.33E-11	2.90E-11	-1.495	0.147
Trade Balance Lag 2	2.10E-12	1.95E-11	0.108	0.915
For-ex Reserves Lag 0	-7.23E-11	1.62E-11	-4.464	0
For-ex Reserves Lag 1	5.33E-11	2.51E-11	2.123	0.044
For-ex Reserves Lag 2	2.43E-11	2.25E-11	1.081	0.29
Net Inflows FDI Lag 0	0.102	0.887	0.115	0.909
Net Inflows FDI Lag 1	2.4117	1.08	2.234	0.035
Net Inflows FDI Lag 2	-2.3142	1.091	-2.121	0.044
Interest Rate Lag 0	-0.146	0.169	-0.863	0.396
Interest Rate Lag 1	-0.0529	0.172	-0.308	0.761
Interest Rate Lag 2	-0.3441	0.191	-1.804	0.083
GDP Growth Diff Lag 0	-0.3615	0.148	-2.448	0.022
GDP Growth Diff Lag 1	-0.2081	0.141	-1.471	0.154
GDP Growth Diff Lag 2	0.1075	0.108	0.993	0.33

India and the US had a negative effect at lag 2, suggesting that a higher relative GDP growth led to INR depreciation. This counterintuitive result might be explained by increased imports and capital outflows, as stronger economic growth may increase external spending and dependency on foreign goods. The fact that this effect is only significant after two periods suggests that the impact of GDP growth differential on exchange rates is not immediate but manifests over time as trade patterns and investment responses adjust.

The ECM results further clarified the nature of these relationships. From Table 6, We note that the actual R-squared statistic is less than ideal (0.257, 0.130 when adjusted), but the F-statistic probability of 0.0887 makes the results significant at 10%, and thus worthy of report. Trade balance remained a significant factor in exchange rate stability, while foreign exchange reserves continued to exhibit a short-term destabilizing effect. However, the error correction term was not statistically significant, indicating that exchange rate deviations do not quickly correct back to equilibrium. This suggests that external shocks such as global crises discussed previously have prolonged effects on the INR/USD exchange rate, requiring strong policy interventions rather than automatic market corrections.

CONCLUSION

This study demonstrates that the INR/USD exchange rate is shaped by a complex interplay of structural factors and exogenous shocks. Among the macroeconomic variables tested, foreign exchange reserves and trade balance were the most significant, though their effects did not always align with conventional expectations. Reserves destabilized the Rupee in the short run before contributing to stabilization, reflecting the reactive nature of RBI interventions. Trade balance improvements were associated with depreciation rather than appreciation, suggesting that capital inflows and import demand offset the traditional competitiveness channel.

The role of foreign direct investment inflows was also nuanced. While inflows initially supported the Rupee, their effects reversed in subsequent periods as profits were repatriated, highlighting the importance of policies that encourage long-term reinvestment. GDP growth differentials with the U.S. had a counterintuitive lagged effect, where stronger Indian growth coincided with depreciation, likely due to increased import intensity of growth. Interest rate differentials, meanwhile, were statistically weaker, suggesting limited explanatory power compared to reserves or FDI.

The analysis of exogenous shocks further reveals that events such as the Global Financial Crisis, demonetization, and COVID-19 produce lasting volatility rather than temporary disruptions. The error correction term was insignificant, implying that exchange rate deviations do not quickly return to equilibrium after shocks. This underscores the vulnerability of India's exchange rate regime to global and domestic crises and highlights the need for deliberate policy action.

For policymakers, the results emphasize that reliance on automatic market correction is insufficient. Instead, stability requires proactive reserve management, fostering reinvestment of FDI, and policies that address the import-intensive nature of growth. More broadly, this study contributes to the literature by showing that in emerging economies like India, exogenous shocks have asymmetric and persistent effects on exchange rate dynamics, extending beyond the predictions of traditional models such as PPP or IRP.

Table 6. ECM Results on the exchange rate: Displays how short-term deviations adjust back toward long-run equilibrium in the exchange rate model

Variable	Coefficient	Std. Error	t	p-value
const	2.2717	0.393	5.775	0.0
Trade Balance	4.067E-11	1.78E-11	2.287	0.028
For-Ex Reserves	-3.439E-11	1.25E-11	-2.753	0.009
Net Inflows FDI	0.0658	0.855	0.077	0.939
Interest Rate	0.1039	0.159	0.655	0.517
GDP Growth Diff	0.0757	0.122	0.619	0.54
ECM Term	0.0158	0.285	0.055	0.956
R-squared Adjusted R-squared Log likelihood	0.257 0.13 -88.594	F-statistic Prob (F-statistic)		2.023 0.0887

CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest related to this work.

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