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INFLUENCE OF KEY ECONOMIC FACTORS ON EXCHANGE RATE USING VECTOR ERROR CORRECTION METHOD: THE CASE OF INDIA

Abstract

The relationship between exchange rates and key economic factors is crucial and may vary across countries depending on the economic context. This paper analyzes cointegration relationships among exchange rate, balance of payments, interest rate, inflation, and trade openness using the Johansen Cointegration Test in the context of the Indian economy. The study uses annual time-series data from 2008 to 2024. Stationarity of the variables is first tested using the Augmented Dickey-Fuller test. The Johansen Cointegration Test is then applied to identify long-run equilibrium relationships, while a Vector Error Correction Model captures short-term dynamics and adjustments towards equilibrium. The exchange rate makes modest adjustments across cointegrating relationships, sometimes restoring equilibrium, other times diverging from it. The balance of payments shows large coefficients, primarily amplifying deviations. The interest rate has minimal adjustment, showing little response to disequilibrium. Inflation and trade openness have small, negative coefficients, indicating weak correction toward equilibrium. Overall, the balance of payments amplifies deviations, while other variables show varying degrees of error-correcting behavior. The model explains 67.4% of the variation in exchange rate changes (R-squared = 0.674), with an adjusted R-squared of 0.5, accounting for predictors. The F-statistic (3.87, p = 0.0115) shows the model is statistically significant. Short-run changes in the exchange rate are influenced by past exchange rates, balance of payments, inflation, and trade openness, while interest rates play a minimal role.

Keywords exchange rate, balance of payment, inflation rate, interest rate, trade openness

JEL Classification C32, F31, F62

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INTRODUCTION

Given different acceptable currencies in different countries of the world, the numerical relationship between these currencies is of paramount importance to foster international trade. This relationship is represented through exchange rates, which denote the number of units of other currency that can be bought with a unit of one currency. In the national context, exchange rates deserve importance due to their impact on a nation's prosperity and international reputation to some extent. Changes in exchange rates impact the receivables and payables in home currency for importers and exporters, as well as the import bills for nations. Particularly, stability of exchange rates is conducive to a nation's exports, overall foreign trade, and economic growth.

A myriad of factors affect exchange rates between currencies of different nations. The connection exists between a country's macroeconomic factors and its exchange rates. These include the nation's balance of payments account, economic growth, inflation rates, and interest

rates. Countries with a BOP surplus and lower inflation tend to witness stability and strength of their currencies. Trade openness, which results in increased contribution of foreign trade in a nation's GDP, is another determinant affecting exchange rate stability. A higher degree of trade openness has been associated with reduced exchange rate volatility. Overall, the interplay of these factors forms the foundation for understanding both short-term fluctuations and long-term trends in exchange rates.

Considering that economic contexts differ from country to country, which may influence exchange rates differently, research in the realm of exchange rate determinants for individual nations is required to shed light on this aspect. Further, the determinants of exchange rates can manifest in different magnitudes and directions in the short run and the long run. This study aims to test a model based on the variables trade openness, interest rates, inflation, exchange rates, and BOP position in the context of an emerging economy, India, which has adopted a flexible exchange rate system since 1991. The influence of these determinants of exchange rates is evaluated for the Indian currency, the Rupee. Using econometric models, the study aims to answer the following question: How do economic variables such as interest rate, inflation rate, balance of payment, and trade openness influence the exchange rate in the short and long run?

1. LITERATURE REVIEW

Exchange rates and their volatility drive a nation's economic growth and impact inflation rates and trade. This statement is more accurate in emerging economies, especially those with flexible exchange rate regimes. Individuals and researchers have always been intrigued by the numerical representation of currencies and the factors affecting them. Further, opinions of industrialists, the general public, and the Government differ in this context. Many people are of the view that a strong currency, particularly a stable currency, is a reflection of a nation's economic strength (Elfaki, 2018; Ahmed et al., 2024). At the same time, there have been cases wherein the currency of a stronger nation has a lesser value, and some nations indulge in competitive devaluation (Subramanian & Kessler, 2013). This has given rise to many academic studies diving into various factors affecting exchange rates. Some of these factors have been foreign exchange reserves (Saeed et al., 2012), trade openness (Raza & Afshan, 2017), capital inflows (Oriavwote & Oyovwi, 2012), and trade imbalance (Ahmed et al., 2024). Further, factors resulting in exchange rate volatility, including their intensity, differ across countries, and their evaluation is critical for the formulation of a correct policy response (Mpofu, 2021).

Purchasing power parity (PPP) theory suggests that exchange rates between two countries must equalize the price levels of various goods and services in different countries. Countries with higher rates of inflation experience a fall in their currencies vis-à-vis countries with lower inflation. Lothian (2016) demonstrated the legitimacy of PPP in the case of fixed and floating exchange rate regimes. However, PPP may not be validated in the short run. Whereas in the long run, PPP theory does manifest, owing to the forces of arbitration and resource re-allocation. PPP theory does stand in the context of key advanced and African emerging economies (Kyei-Mensah, 2023). Peng et al. (2017) validated the implications of PPP in the context of BRICS nations. Fisher (1930) postulates that the nominal exchange rate is the summation of real exchange rates and expected inflation. Hence, different interest rates in different countries will lead to the corresponding change in nominal exchange rates. This relationship between exchange rates and inflation, suggested by PPP theory and Fisher, has been confirmed by a number of research studies. Draz et al. (2019) demonstrated interest rates and exchange rates as significant determinants of exchange rates in South Asian economies. According to the interest rate parity theory, forward exchange rates adjust to interest rate parities (Keynes, 1923). Interest rates should be prioritized as an effective policy tool for mitigating short-term exchange rate volatility. Higher interest rates lead to currency depreciation. However, Shodipe (2018) found a positive connection between the real interest rate and real exchange rate in Japan. Thus, interest rate differentials between the nations be-

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come another formidable force in influencing exchange rates. Major studies on the relationship between these variables show a negative relationship in the short run and a positive relationship in the long run (Frankel, 1979; Scott Hacker et al., 2012). The sensitivity of the exchange rate to interest rate was demonstrated by Atoi et al. (2021), in the context of Nigeria, and Elfaki (2018) for Sudan. Expansion of real GDP growth rate leads to a stable exchange rate (Elfaki, 2018). Surplus on BOP account leads to appreciation of Real Effective Exchange Rate (REER). Trade openness, which represents the contribution of international trade to a nation's GDP (Dowrick & Golley, 2004), is another significant determinant of exchange rates. Trade openness speeds up the technical prowess of a nation, thereby ensuring higher productivity of production factors. Higher productivity, in turn, leads to a surge in exports and ensures stability in exchange rates. Stancık (2006) found that trade openness reduced exchange rate volatility for six newly joined member nations to the European Monetary Union in 2004. In the case of Egypt, trade openness was associated with a significant positive impact on exchange rates in the short run (Abdelgany, 2020). Likewise, Amor and Sarkar (2008) found decreased exchange rate volatility with economic openness of Southeast Asian nations. Appreciation or depreciation of a nation's currency with a significant degree of trade openness depends upon the structure of foreign trade. Turkey witnessed a fall in its currency, the Lira, from 2004–2018 as its imports continually surpassed exports (Aslan, 2020). Similarly, Malaysian currency depreciated due to trade openness (Lee & Law, 2013). The impact of macroeconomic fundamentals such as interest rates and GDP on exchange rates is less in economies with a higher degree of trade openness.

Balance of payments (BOP), which indicates the transactions between a specific country and the rest of the world, is a crucial determinant of a country's exchange rate, since international currency flows are driven by BOP transactions. Theoretically, a deficit in BOP results in currency depreciation. This is because of a higher foreign currency demand necessary to pay for imports. BOP has critical implications for the movements of nominal and real exchange rates. This relationship can further explain currency crises, or the probability of the same, in different countries. Iyoboyi and Muftau (2014) found bidirectional causality between exchange rates and BOP. Kumar (2021) revealed a correlation between BOP and exchange rates. A significant negative long-run relationship exists between real exchange rates and current account balance (Arghyrou & Chortareas, 2008). Real exchange rates of a nation depend on its cumulative trade and capital flows. Differentials in trade balance are an important determinant of exchange rates. Exchange rates are considerably affected by trade balance announcements (Doukas & Lifland, 1994). Exchange rate volatility is negatively impacted by foreign reserves volatility, which in turn is affected by BOP. Economic cycles influence exchange rates with BOP as a moderating variable (Kirianki, 2024). Exchange rates tend to behave differently during boom and bust cycles. Capital flows surpass the current account deficit (CAD) during the initial economic expansion. However, this capital is withdrawn during the subsequent downturn, impacting BOP severely and causing currency depreciation. Countries experiencing CAD see the depreciation of their currency, and vice versa.

Thus, different studies can be seen in the context of determining exchange rates in developed and developing countries. These studies consider the intensity of one or some factors to be higher than the others, and the results vary from nation to nation.

Different economic and trade structures influence exchange rates, and different elements affect them. This fact entails studying the determinants of exchange rates on a country-specific basis. Further, most literature in this arena shows that exchange rates are highly influenced by trade openness, balance of payment situation, inflation, and interest rate differentials. It thus becomes important to study and measure the impact of these macroeconomic factors on the exchange rates, particularly in emerging economies.

Hence, the objective of this study is to determine the combined effect of trade openness, balance of payments, inflation, and interest rate differentials on exchange rates in the context of one of the major emerging nations, India, through an integrative model.

2. METHODS

The analysis uses time-series data for the following variables: Exchange Rate, Balance of Payments, Interest Rate, Inflation, and Trade Openness. The data span multiple periods from 2008 to 2024, and their frequency is annual, which corresponds to the periodicity necessary for macroeconomic analysis. The study is conducted within the context of a specific country or region (India). The time frame for the analysis is also defined by the availability of relevant data on the chosen variables, spanning 17 years, to capture both long-term trends and short-term fluctuations in exchange rates. Before applying the Johansen Cointegration Test, stationarity is checked for each variable using the Augmented Dickey-Fuller test. This ensures that the time series are integrated of the same order, typically I(1), meaning they are non-stationary in levels but become stationary after first differencing. The Johansen Cointegration Test is applied to examine the existence of long-run equilibrium relationships among the variables. This test uses the following components: Model Specification: The model used is without a linear trend and constant in the cointegration equation, testing the hypothesis of cointegration vectors. Trace Statistic: The trace statistic tests for the number of cointegrating vectors. The null hypothesis for the test is that there are "r" or fewer cointegrating relationships. The critical values are set at the 5% level. Eigenvalues and Eigenvectors: The lambda eigenvalues represent the strength of the cointegrating vectors. Larger eigenvalues indicate stronger relationships, while smaller values suggest weaker or no cointegration. The number of significant eigenvalues determines the number of cointegrating vectors. Cointegrating Vectors: Each eigenvector corresponds to one long-run equilibrium relationship. The coefficients in each eigenvector show how the variables combine to form a stationary process.

2.1. Theoretical model of the study

The theoretical foundation of this study is based on several economic theories that explain the behavior of exchange rates in relation to macroeconomic variables. The theoretical model links the exchange rate with key determinants such as the balance of payments, interest rates, inflation, and trade openness. Below are the primary theories that underpin the study:

2.1.1. Purchasing Power Parity (PPP) Theory

This theory postulates that in the long run, exchange rates should adjust to equalize the price of identical goods and services across different countries. This implies that the exchange rate between two currencies will move in response to the relative inflation rates of the countries. Mathematical representation:

$$E\_Rate = \frac{P\_domestic}{P\_foreign}, \quad (1)$$

where *E_Rate* is the exchange rate, *P_domestic* is the price level in the domestic country, *P_foreign* is the price level in the foreign country.

This theory(1) implies that higher domestic inflation leads to a depreciation of the local currency, while lower inflation leads to an appreciation.

2.1.2. Interest Rate Parity (IRP) Theory

This theory suggests that differences in interest rates between two countries are a primary driver of exchange rate movements. In an open economy, if the interest rate in a country is higher than in another, capital will flow toward the higher-yielding country, leading to an appreciation of its currency.

Mathematical representation:

$$E\_Rate = \left(\frac{1+I\_domestic}{1+I\_foreign}\right)^n, \quad (2)$$

where *I_domestic* is the domestic interest rate, *I_foreign* is the foreign interest rate, and *n* is the number of years. This theory (2) posits that exchange rates will adjust to offset differences in interest rates between countries, ensuring no arbitrage opportunities.

2.1.3. Monetary Approach to the Exchange Rate

The Monetary Approach considers the exchange rate as a function of the supply and demand for money in an economy. It emphasizes that factors affecting the money supply (e.g., inflation, interest rates) also affect the exchange rate. Countries with higher money supply growth tend to experience inflation, leading to a depreciation of their currency.

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Mathematical model:

$$E\_Rate = \frac{M\_domestic}{M\_foreign} \cdot \frac{Y\_foreign}{Y\_domestic}, \quad (3)$$

where M is the money supply, and Y is the output (GDP).

This approach (3) suggests that a higher domestic money supply or lower economic output relative to the foreign economy leads to currency depreciation.

2.1.4. Balance of Payments (BOP) Theory

This theory posits that a country's exchange rate is influenced by its international trade and capital flows. A trade surplus (exports > imports) leads to an inflow of foreign currency, causing an appreciation of the domestic currency, while a trade deficit causes depreciation. Similarly, capital inflows (e.g., foreign investment) lead to currency appreciation, while capital outflows cause depreciation.

Model representation:

$$ERate = f\left(BOP\_current,\ BOP\_capital\right), \quad (4)$$

where *BOP_current* is the current account balance, and *BOP_capital* is the capital account balance.

This model (4) highlights the relationship between the exchange rate and a country's external position in terms of trade and financial flows.

2.1.5. Trade Openness

Trade Openness refers to the extent to which a country engages in international trade (exports and imports). Greater trade openness tends to reduce exchange rate volatility as it increases the flow of goods, services, and capital, making the currency more liquid. Conversely, less open economies are more susceptible to exchange rate fluctuations due to lower external engagement.

Model representation:

$$E\_Rate = f\left(Trade\ Openness\right), \quad (5)$$

where *Trade Openness* is typically measured as the ratio of the sum of exports and imports to GDP.

2.1.6. Integrative Theoretical Model

Bringing these theories or models [(1), (2), (4), (5)] together, the study proposes a model where the exchange rate is determined by multiple factors, including balance of payments, interest rates, inflation, and trade openness.

The general form of the theoretical model can be represented as

$$E\_Rate = f\left(BOP,\ IR,\ INF,\ Trade\_O\right), \quad (6)$$

where *E_Rate* is the exchange rate, *BOP* represents the balance of payments (current and capital accounts), *IR* is the domestic interest rate, *INF* is the inflation rate, and *Trade_O* is the level of trade openness.

This theoretical model (6) suggests that the exchange rate is a function of a country's external position (balance of payments), domestic macroeconomic policies (interest rates and inflation), and its engagement with the global economy (trade openness). The analysis will use this framework to examine both the long-run and short-run dynamics of exchange rate fluctuations in relation to the selected macroeconomic variables.

2.2. Vector Error Correction Method (VECM)

VECM is employed to model the short-term dynamics of the system while maintaining long-run equilibrium through the error correction mechanism. The loading matrix (W) indicates how each variable adjusts to deviations from the long-run equilibrium. Negative coefficients indicate error-correcting behavior, while positive ones suggest amplification of disequilibrium. The error correction terms (ECT1, ECT2, ...) in the VECM indicate the speed of adjustment towards the long-run equilibrium. Lagged values of the variables, including exchange rate, balance of payments, interest rate, inflation, and trade openness, are incorporated into the model to capture short-term relationships. The residuals from the VECM are analyzed for serial correlation using the Breusch-Godfrey LM test. Additionally, the model's goodness of fit is evaluated using the *R*-squared and Adjusted R-squared values, alongside the F-statistic to check overall significance.

2.3. Theoretical and practical boundaries

The study is based on classical and contemporary theories of exchange rate determination, including Purchasing Power Parity (PPP), relating exchange rate movements to inflation differentials. Interest Rate Parity (IRP) links exchange rate dynamics to differences in interest rates between countries. Monetary and Balance of Payments Theories explore how trade balances and external financial flows impact currency valuation.

The scope of this study revolves around examining the relationship between key macroeconomic variables and the exchange rate using econometric techniques. Specifically, the analysis identifies both the long-run equilibrium and short-term dynamics between the following five variables.

3. RESULTS

3.1. Johansen test overview

In the Johansen cointegration test, eigenvalues are crucial in determining the number of cointegrating relationships among a set of non-stationary time series. Here is how to interpret the eigenvalues: It tests for the number of cointegrating vectors (long-run equilibrium relationships) in a group of time series. Test type: using the trace statistic without a linear trend and constant term in the cointegration equation. The trace statistic tests whether the number of cointegrating relationships is equal to or less than a given number (denoted by r). The eigenvalues, denoted as λ, are directly related to the strength of the cointegrating relationships. Larger eigenvalues suggest stronger cointegration, while smaller eigenvalues imply weaker relationships. Eigenvalue (λ): Each eigenvalue corresponds to the strength of a potential cointegrating vector. If a significant eigenvalue is large, it suggests a strong cointegrating relationship. If it's near zero, no cointegration exists for that vector. The number of significant eigenvalues determines the number of cointegrating relationships. Eigenvalues (λ) = [0.8393, 0.7334, 0.6334, 0.4361, 0.1458, 0.0000]

The first eigenvalue (0.839) is the largest, suggesting a strong cointegrating relationship. The second eigenvalue (0.733) is still large, implying another strong cointegrating relationship. The third eigenvalue (0.633) shows a weaker, but still relevant, cointegrating vector. The fourth eigenvalue (0.436) is moderate in size and could indicate a weak cointegration. The fifth eigenvalue (0.146) is small and suggests minimal cointegration. The sixth eigenvalue (0.000) indicates no further cointegrating relationships.

Table 1. Values of the test statistic and critical values of the test

r	Test value	At 5 %
r <= 4	3.62	9.24
r <= 3	16.80	19.96
r <= 2	39.88	34.91
r <= 1	70.29	53.12
r = 0	112.34	76.07

The output in Table 1 represents the Johansen cointegration test, which tests the number of cointegrating relationships (denoted by *r*) in a multivariate time series model. Specifically, this is the trace test used to determine the number of cointegrating vectors. Each row provides a test statistic. This is the computed trace statistic for the corresponding hypothesis. There are critical values at different significance levels (5%) that the test statistic is compared against to determine whether to reject the null hypothesis. Decision Rule: If the test statistic exceeds the critical value at a given significance level (5% is commonly used), the null hypothesis that there is "*r*" or fewer cointegrating relationships is rejected. If the test statistic is below the critical value, we fail to reject the null hypothesis and conclude that the number of cointegrating relationships is at most "*r*". Based on the Johansen trace test results, we reject the hypotheses for *r* = 0, *r* <= 1, and *r* <= 2, but fail to reject for *r* <= 3 and *r* <= 4. This implies three cointegrating relationships among the variables, as the test rejects the null hypothesis up to *r* <=2, but not beyond *r* <= 3. Therefore, the model suggests the presence of three long-run equilibrium relationships among the variables. This finding indicates that the variables are co-integrated and that their long-term behavior is influenced by these three equilibrium relationships.

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Table 2. Eigenvectors

	E_Rate.l2	*BOP.l2*	*IR.l2*	*INF.l2*	*Trade_O.l2*	*constant*
E_Rate.l2	1.00000	1.00000	1.000000	1.00000	1.00000	1.00000
BOP.l2	–0.0000814	–0.00002269	–0.0002052	0.00002227	–0.00009631	0.0000007092
IR.l2	–184.069443	–145.413273	1264.30172	1226.956062	–1865.774459	176.90743193
INF.l2	0.6987517	9.316605	–4.142844	5.524634	22.697620	–0.25994674
Trade_O.l2	94.612579	–286.272763	–326.00117	–134.413004	–655.156598	–37.54596669
Constant	–74.417272	33.257339	56.3020153	–108.833184	138.578766	–50.163912

Note: *E_Rate.l2* – Exchange Rate lagged by 2 periods, *BOP.l2* – Balance of Payment lagged by 2 periods, *IR.l2* – Interest Rate lagged by 2 periods, *INF.l2* – Inflation Rate lagged by 2 periods, *Trade_O.l2* – Trade Openness lagged by 2 periods, and *Constant* – the intercept term.

3.1.1. Eigenvectors (Cointegrating Relations)

The Johansen test (see Table 2) provides cointegrating vectors represented by the eigenvectors. Each eigenvector represents a long-run equilibrium relationship among the variables in the system. Here is how to interpret the key elements of the output in Table 3: First, eigenvectors describe the cointegrating relationships between the variables. Second, values in each row represent the coefficients of the variables in the cointegration equation. Third, each matrix column represents one cointegrating relationship, which tells us how a linear combination of the variables results in a stationary process.

$$\begin{aligned} &E\_Rate.l2 = 0.0000814 \cdot BOP.l2 \\ &+184.07 \cdot IR.l2 - 0.699 \cdot INF.l2 \\ &-94.613 \cdot Trade\_O.l2 + 74.417, \end{aligned} \tag{7}$$

3.1.2. First cointegrating vector

In the first cointegrating equation (7), *E_Rate.l2* has a strong negative relationship with *Trade_O.l2* and *INF.l2*, and a strong positive relationship with *IR.l2. BOP.l2* has a negligible effect (small coefficient). This suggests that an increase in the interest rate or trade openness significantly affects the exchange rate, while the balance of payments has a little influence.

$$\begin{aligned} &E\_Rate.l2 = 0.00002269 \cdot BOP.l2 \\ &+145.413 \cdot IR.l2 - 9.317 \cdot INF.l2 \\ &+286.273 \cdot Trade\_O.l2 - 33.257, \end{aligned} \tag{8}$$

3.1.3. Second cointegrating vector

In this second relationship (8), *IR.l2*, *Trade_O.l2* have a strong positive relationship with *E_Rate.l2*, but *INF.l2* has a negative effect on the exchange rate lagged by two periods. In the first cointegration equation, the constant term (74.417) is positive, i.e., average value of *E_Rate.l2,* and in the second cointegration equation, the constant term (–33.257) is negative, i.e., average value of *E_Rate.l2*. This suggests a different interaction pattern between these variables compared to the first equation. It might be due to a change in the average value of the exchange rate lagged by two periods.

$$\begin{aligned} &E\_Rate.l2 = 0.0002052 \cdot BOP.l2 \\ &-1264.3 \cdot IR.l2 + 4.143 \cdot INF.l2 \\ &+326.00 \cdot Trade\_O.l2 - 56.302, \end{aligned} \tag{9}$$

3.1.4. Third cointegrating vector

In this vector (9), the interest rate lagged by two periods has an extremely large negative coefficient, indicating a very strong negative impact on the exchange rate lagged by two periods. Trade openness lagged by two periods has a strong positive effect, and inflation lagged by two periods has a small positive effect. According to eigenvalues, the cointegration strength among variables is 0.6334 for the third cointegration, which is weak as compared to the first two eigenvalues, 0.8393 and 0.7334. So, researchers might give less weight to the third cointegration equation as compared to the first two equations. All three cointegration equations show little or negligible effect of balance of payment on exchange rate in the long run. The last three columns of Table 3 are not under study due to no long-run cointegration among variables.

In the Johansen test, the weights matrix in Table 3 (also known as the loading matrix, W) represents how each variable adjusts in the short run to de-

Table 3. Loading matrix W

	E_Rate.l2	*BOP.l2*	*IR.l2*	*INF.l2*	*Trade_O.l2*	*constant*
E_Rate.d	–0.0163272	0.008244	–0.030901985	0.0907886	–0.00773353	$-2.6*10^{-16}$
BOP.d	14125.920798	–28.1529	2336.5947208	–6950.3937	–294.22356	$-1.2*10^{-10}$
IR.d	0.0001924	0.000282	–0.00008556	–0.0002177	0.00003054	$-5.7*10^{-19}$
INF.d	–0.0337706	–0.02094	–0.00572046	–0.0387116	–0.00648418	$-2.1*10^{-16}$
Trade_O.d	–0.0019628	0.00116	–0.000000049	0.0002742	–0.00004479	$2.0*10^{-17}$

Note: *E_Rate.d* – change in Exchange Rate, *BOP.d* – change in Balance of Payment, *IR.d* – change in Interest Rate, *INF.d* – change in inflation), and *Trade_O.d* – change in Trade Openness.

viations from the long-run equilibrium relationships (cointegrating vectors). Rows represent the dependent variables in their first differences (like *E_Rate.d, BOP.d*, etc.), which indicate changes over time. Columns represent the independent variables, including lagged terms (like *E_Rate.l2*, *BOP.l2*, etc.) and the constant.

The short-run deviations are captured by the error correction terms in a Vector Error Correction Model (VECM). Weights (Loading Matrix) provide adjustment coefficients for each variable in response to deviation from the long-run cointegrating relationships. Negative coefficient means the variable responds by adjusting towards the long-run equilibrium (error-correcting behavior). A positive coefficient means the variable moves away from the long-run equilibrium, potentially amplifying the disequilibrium. Larger values indicate stronger adjustment to restore equilibrium when the system is out of balance. Smaller values (near zero) indicate weak or negligible adjustment.

From row one in Table 3, *E_Rate.d* (Change in Exchange Rate): A one-unit increase in the exchange rate lagged by 2 periods will decrease the current exchange rate (*E_Rate*) by 0.0163272 units. Similarly, a one-unit increase in *BOP.l2* (Balance of Payment lagged by 2 periods), *IR.l2* (Interest Rate lagged by 2 periods), *INF.l2* (Inflation Rate lagged by 2 periods), and *Trade_O.l2* (Trade Openness lagged by 2 periods) will change the current exchange rate by 0.008244, –0.030901985, 0.0907886, –0.00773353 units, respectively. Constant -2.6×10^{-16} is zero and has a negligible effect on the exchange rate change. Since the coefficient adjustment values for all the variables are very small, this indicates weak adjustments in the coefficients of all variables to maintain the long-run equilibrium and have minimal effect on the change of the current exchange rate. *E_Rate.l2*, *IR.l2*, and *Trade_O.l2* variables respond by adjusting towards restoring the equilibrium due to negative coefficients, and *BOP.l2*, *INF.l2* variables move away from the equilibrium, potentially amplifying the disequilibrium due to positive coefficients.

From row second in Table 3, *BOP.d* (Change in Balance of Payments): A one-unit change in *E_Rate.l2* (Exchange Rate lagged by 2 periods), *BOP.l2* (Balance of Payment lagged by 2 periods), *IR.l2* (Interest Rate lagged by 2 periods), *INF.l2* (Inflation Rate lagged by 2 periods), and *Trade_O.l2* (Trade Openness lagged by 2 periods) will change the current Balance of Payments by 14125.92, –28.15, 2336.59, –6950.39, –294.22 units, respectively. Constant -1.2×10^{-10} is effectively zero and has a negligible effect on the balance of payment change. A one-unit increase of each variable lagged by two periods will have a very strong adjustment in the coefficients of each variable lagged by two periods. It might be due to the very large average value of the balance of payments. From row third in Table 3, *IR.d* (Change in Interest Rate): a one-unit change in *E_Rate.l2* (Exchange Rate lagged by 2 periods), *BOP.l2* (Balance of Payments lagged by 2 periods), *IR.l2*(Interest Rate lagged by 2 periods), *INF.l2*(Inflation Rate lagged by 2 periods), and *Trade_O.l2* (Trade Openness lagged by 2 periods) will change the current Interest Rate by 0.0001924, 0.000282, –0.0000855, –0.0002177, and 0.00003054 units, respectively. Constant -5.7×10^{-19} is effectively zero and has a negligible effect on the interest rate change. From row four in Table 3, *INF.d* (Change in Inflation Rate): A one-unit change in *E_Rate.l2* (Exchange Rate lagged by 2 periods), *BOP.l2* (Balance of Payment lagged by 2 periods), *IR.l2* (Interest Rate lagged by 2 periods), *INF.l2* (Inflation Rate lagged by 2 periods), and *Trade_O.l2* (Trade Openness lagged by 2 peri-

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ods) will change the current Inflation Rate by −0.0337706, −0.02094, −0.00572046, −0.0387116, and −0.00648418 units, respectively. Constant -2.1×10^{-16} is zero and has a negligible effect on the inflation change. From row five in Table 3, *Trade_O.d* (Change in Trade Openness): A one-unit change in *E_Rate.l2* (Exchange Rate lagged by 2 periods), *BOP.l2* (Balance of Payment lagged by 2 periods), *IR.l2* (Interest Rate lagged by 2 periods), *INF.l2* (Inflation Rate lagged by 2 periods), and *Trade_O.l2* (Trade Openness lagged by 2 periods) will change the current Inflation Rate by −0.0019628, 0.00116, −0.000000049, 0.0002742, and −0.00004479 units, respectively. Constant 2.0×10^{-17} is effectively zero and has a negligible effect on the trade openness change. It is observed that a one-unit change in each variable lagged by two periods has a very negligible adjustment in the coefficient of each variable lagged by two periods and will have a negligible effect on the change of current Interest rate, Inflation, and Trade openness.

3.2. Vector Error Correction Model (VECM)

Table 4. Residuals

Min	1Q	Median	3Q	Max
−3.758	−1.069	0.095	1.329	3.863

The residuals in Table 4 describe how well the model fits the data. This indicates the deviation between the actual data and the model's predictions: Min, 1Q, Median, 3Q, and Max. These values represent the distribution of the residuals (errors). Since the median is close to zero, the model's predictions are fairly balanced.

$$E\_Rate.d = ect1 + ect2 + ect3 + E\_Rate.dl1 + BOP.dl1 + IR.dl1 + INF.dl1 + Trade\_O.dl1 - 1, \quad (10)$$

3.2.1. Vector Error Correction Model

In the Vector Error Correction Model (VECM), the output (see Table 5) shows the regression results for the differenced exchange rate (*E_Rate.d)* (eq.10) as the dependent variable. The coefficients in Table 5 represent the impact of each explanatory variable (error correction terms and lagged variables) on the change in the exchange rate (*E_Rate.d*). The coefficient of the first error correction term, ect1 (−0.03898), related to the first cointegrating vector, is negative but statistically insignificant (p = 0.462). This means that deviations from the long-run equilibrium defined by the first cointegrating vector have a weak and statistically insignificant effect on the change in the exchange rate. The second error correction term, *ect2* (0.00000748), is very small and also insignificant (p = 0.116). This suggests that deviations from the second long-run equilibrium relationship also do not significantly impact the exchange rate. The third error correction term, ect3 (–37.26), has a large coefficient and is marginally significant (p = 0.072). This indicates that deviations from the long-run equilibrium in the third cointegrating vector have a stronger (negative) influence on changes in the exchange rate, but the effect is not fully statistically significant.

Table 5. Coefficients

	Estimate	Std. Error	t value	Pr(>|t|)
ect1	−0.03898466	0.05167929	−0.75	0.462
ect2	0.00000748	0.00000449	1.67	0.116
ect3	−37.26295746	19.23401296	−1.94	0.072
E_Rate.dl1	0.44244557	0.21411123	2.07	0.057
BOP.dl1	0.00001216	0.00000344	3.53	0.003 **
IR.dl1	−37.07793280	63.02792897	−0.59	0.565
INF.dl1	−1.11996515	0.39599020	−2.83	0.013 *
Trade_O.dl1	44.25068334	18.42631270	2.40	0.030 *

Note: Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Residual standard error: 2.28 on 15 degrees of freedom. Multiple R-squared: 0.674, Adjusted R-squared: 0.5. F-statistic: 3.87 on 8 and 15 DF, p-value: 0.0115. *ect1* – first error correction term, *ect2* – second error correction term, *ect3* – third error correction term, *E_Rate.dl1* – change in exchange rate lagged by one period, dependent variable, *BOP.dl1* – change in balance of payment lagged by one period, *IR.dl1* – change in interest rate lagged by one period, *INF.dl1* – change in inflation lagged by one period, and *Trade_O.dl1* – change in trade openness lagged by one period.

The change in exchange rate lagged by one period, *E_Rate.dl1* (0.442), has a positive and marginally significant impact on current changes in the exchange rate (p = 0.057). This suggests that past changes in the exchange rate positively affect current changes, indicating momentum in the short run. The shift in balance of payments lagged by one period, *BOP.dl1* (0.00001216), has a positive and highly significant impact on the current exchange rate (p = 0.003). This means that an improvement in the balance of payments tends to positively affect the exchange rate in the short run. The change in interest rate lagged by one period, *IR.dl1* (–37.08), has a negative but statistically insignificant effect (p=0.565). This suggests that changes in the interest rate have no meaningful short-run effect on the current exchange rate in this model. The change in inflation rate lagged by one period, *INF.dl1* (–1.12), has a negative and statistically significant impact on the current exchange rate (p = 0.013). This implies that higher past inflation tends to reduce the exchange rate (appreciation of the currency) in the short run. The change in trade openness lagged by one period, *Trade_O.dl1* (44.25), has a positive and statistically significant effect on the current exchange rate (p = 0.030). This means that an increase in trade openness tends to increase the exchange rate in the short run (depreciation of the currency).

3.2.2. *Significant variables*

The change in Balance of Payments lagged by one period (*BOP.dl1*) has a strong positive impact on the exchange rate in the short run. The change in inflation lagged by one period (*INF.dl1*) has a negative short-run impact on the exchange rate. The change in Trade Openness lagged by one period (*Trade_O.dl1*) has a positive effect on the exchange rate.

3.2.3. *Marginally significant variables*

The change in the Exchange Rate lagged by one period (*E_Rate.dl1*) has a positive impact with momentum effects. The third Error Correction Term (*ect3*) has some long-run adjustment from the third cointegrating relationship.

3.2.4. *Insignificant variables*

These error correction terms (*ect1, ect2*) do not have a significant effect, suggesting weak long-run adjustment from the first two cointegrating vectors. The change in interest rate lagged by one period (*IR.dl1*) does not play a significant role in determining short-run changes in the exchange rate.

3.2.5. *Model fit*

R-squared (0.674) indicates that the model explains about 67.4% of the variation in the change in the exchange rate, which is relatively good for time series data. Adjusted *R*-squared (0.5) after adjusting for the number of predictors, the model explains about 50% of the variation. *F*-statistic (3.87, p = 0.0115), which indicates that the overall model is statistically significant, meaning the variables jointly explain the changes in the exchange rate.

4. DISCUSSION

The study finds a significant impact of macroeconomic variables on the exchange rates in the Indian context. The results are similar to those of Anita (2013), with the data period 1991 to 2010 and microeconomics variables such as inflation, interest rate, balance of payment, GDP, etc. The Johansen cointegration test reveals the presence of three cointegrating relationships among the variables under study: exchange rate, balance of payments, interest rate, inflation, and trade openness. The eigenvalues and trace statistics confirm the existence of long-run equilibrium relationships among these variables, particularly highlighting the significant role of the interest rate and trade openness in explaining exchange rate behavior. The first two Eigenvalues, 0.8393 and 0.7334, show a very strong cointegration relationship among the variables under study. So, according to the first cointegration vector equation (7), *E_Rate.l2* has a strong negative relationship with *Trade_O.l2* and a very small negative relationship with *INF.l2*. Similar findings are obtained by Ishak (2020) that Trade openness and Inflation (long and short) have a negative effect on the exchange rate in Indonesia from 2004 to 2015. E_Rate.l2 has a strong positive relationship with IR.l2. Similar findings are found by Ajao et.al (2013) in Nigeria from 1981 to 2008. The study found that balance of payments lagged by two periods (*BOP.l2*) has a very small negative effect (small coefficient) on the exchange rate in India, while some studies found an oppo-

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site relation with the exchange rate. Ahmad et al. (2014) have found that balance of payments has a positive impact on the Pakistan exchange rate from 2007 to 2013, and Odili (2014) found a positive relation with the exchange rate in Nigerian data from 1971 to 2012. It might be the case in different time periods and geography where governments have some problems with a strongly effective exchange rate. According to the second cointegration vector, Interest rate and Trade openness lagged by two periods (*IR.l2* and *Trade_O.l2*) play a strong positive relation with the exchange rate, but *INF.l2* now has a large negative effect on the *E_Rate.l2,* and *BOP.l2* has a very small negative effect on the exchange rate. The average values (constant term) of the exchange rate in all three cointegration equations, 74.417272, –33.257339, and –56.3020153, respectively, play an important role in deciding the relationship among variables. The first cointegration has an average positive value of 74.41, which means that if all the independent variables become zero, then the exchange rate value will be 74.41. Similarly, for the cointegration equation, the second and third average values of the exchange rate are –33.25 and –56.30, which give different relationships among dependent and independent variables.

The change in balance of payments lagged by one period, *BOP.dl1* (0.00001216), has a positive and highly significant impact on the current exchange rate in the short term ($p = 0.003$), but Alawattage (2009) and Thahara et al. (2021) have found no impact on the exchange rate in the short term. The results of the Vector Error Correction Model (VECM) show that the balance of payments and inflation are significant short-term drivers of exchange rate fluctuations, similar to Peng et al. (2017) and Kumar (2021), while the interest rate, despite its strong long-term impact, has a negligible short-term effect.

This study is limited to five variables such as the exchange rate, balance of payments, interest rate, inflation, and trade openness. Other macroeconomic variables, such as government debt, foreign reserves, or political stability, along with financial crisis and geopolitical events, might also influence the exchange rate and could provide a more comprehensive analysis if included. When it comes to the analysis part, assumptions have been made that all variables are non-stationary and integrated of the same order. Any deviation from this assumption could lead to biased or inaccurate conclusions regarding cointegration and long-run relationships. Further, the results of the Johansen test and the VECM are sensitive to the choice of lag length and the data period. A different time frame or selection of lags might yield different results, limiting the generalizability of the findings across different economic conditions. While the VECM captures short-term adjustments, it may not fully capture the complexities of real-time market reactions or external shocks. The model may oversimplify the interplay of variables in a highly dynamic economic environment.

CONCLUSION

In the national context, exchange rates deserve importance due to their impact on a country's prosperity and international reputation to some extent. Changes in exchange rates impact the receivables and payables in home currency for importers and exporters, as well as the import bills for nations. Particularly, stability of exchange rates is conducive to a nation's exports, overall foreign trade, and economic growth. With respect to this, researchers have the following findings from the study.

Overall, the Interest Rate across all cointegrating vectors significantly impacts the exchange rate, with very large coefficients, either positive or negative. It appears to be one of the most influential variables. Trade Openness also has a strong impact, though its direction (positive or negative) varies across the cointegrating vectors. Inflation generally has a moderate positive effect on the exchange rate in most cointegrating vectors. Balance of Payments has a very little impact on the exchange rate, as indicated by the tiny coefficients across all vectors. The constant terms also vary widely, suggesting different equilibrium levels in each relationship. The eigenvectors represent various long-run relationships between the exchange rate, balance of payments, interest rate, inflation, and trade openness. The most significant factors affecting the exchange rate appear to be the interest rate and trade openness, while the balance of payments has a minimal effect in all relationships.

The change in exchange rate makes modest adjustments (both positive and negative) across the cointegrating relationships. In some relationships, it helps restore equilibrium, while in others, it moves away from it. The change in balance of payments has very large coefficients in the first cointegrating relationships, but it primarily moves away from equilibrium (positive values), meaning it amplifies deviations from the long-run equilibrium in most cases. The change in the Interest rate has extremely small coefficients across all relationships, indicating that it does not adjust much to deviations from equilibrium. Change in Inflation shows small, negative adjustment coefficients, suggesting it plays a minor role in correcting deviations from long-run equilibrium. The change in Trade openness has very small coefficients, indicating weak adjustment to deviations from equilibrium. So, the loading matrix shows how each variable responds to deviations from the long-run equilibrium relationships described by the cointegrating vectors. In that case, the balance of payments appears to react strongly but typically amplifies deviations rather than correcting them, while the interest rate shows very little response to disequilibrium. The exchange rate, inflation, and trade openness show varying degrees of error-correcting behavior.

Considering the significant long-run impact of interest rates on exchange rates, monetary policy interventions should focus on stabilizing interest rates to maintain exchange rate equilibrium. Central banks should monitor and adjust interest rates in line with their influence on currency stability. Further, the strong role of trade openness in both the long- and short-term calls for policies promoting international trade. Governments in emerging economies should consider strategies to enhance trade relations, reduce barriers, and encourage exports to positively influence the currency value. Since inflation negatively affects the exchange rate in the short term, policies aimed at controlling inflation, such as prudent fiscal policies and supply-side interventions, should be prioritized to prevent currency depreciation. The balance of payments significantly affects the exchange rate in the short run, emphasizing the need for monitoring and managing external financial flows. A focus on improving the balance of payments through exports, remittances, and foreign direct investments could strengthen currency stability.

AUTHOR CONTRIBUTIONS

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