Innovations

Investigating the Non-Linear Relationship between Exchange Rates and Inflation in India

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Abstract: *This study tries to investigate the asymmetric relationship between real effective exchange rate (REER) fluctuations and inflation (INF) in India using the non-linear autoregressive distributed lag (NARDL) approach using annual time series data from 1985 to 2022. The study explores how positive and negative changes in the REER impact INF differently. The findings reveal significant asymmetries in the relationship, indicating that REER appreciations have a more notable effect on INF compared to depreciation in the long run. However, in the short run, only negative changes in REER are significant. Moreover, the error correction term (ECT) shows convergence towards the long run. Additionally, the diagnostic results satisfied the assumptions of the classical linear regression model.*

Keywords: *Exchange rate; inflation; Money supply; Fiscal deficit; Economic growth; Import*

1. Introduction

The intricate relationship between exchange rates and inflation (INF) is a fundamental aspect of macroeconomic theory and policy, particularly in emerging economies. Exchange rates, which define the value of one currency relative to another, directly influence the cost of imports and exports, thereby impacting the overall price level within an economy (Hansi, 2023). Inflation, on the other hand characterized by the general increase in prices and the subsequent decline in the purchasing power of money (Oğul, 2022), is a critical indicator of economic stability. In India, this relationship holds particular significance due to the nation's diverse economic structure, reliance on imports, and exposure to global financial markets.

Historically, India's exchange rate regime has undergone significant transformations, from a fixed to a more flexible system, influencing the inflationary landscape. The interaction between these two macroeconomic variables requires a robust analytical framework to capture the complexities and asymmetries intrinsic in their relationship. Traditional econometric models often assume a symmetric relationship, where positive and negative changes in exchange rates have equal but opposite effects on INF. However, recent empirical evidence suggests that this may not always hold true. Factors such as market expectations, price stickiness, and varying pass-through effects can lead to asymmetric responses. To address these intricacies, the Nonlinear Autoregressive Distributed Lag (NARDL) approach offers a comprehensive methodology. This model allows for the differentiation between positive and negative changes in exchange rates and their distinct impacts on inflation, providing a more accurate depiction of their relationship.

The Indian economy presents an intriguing case for the application of the NARDL model due to its unique economic characteristics and policy environment. The country's inflation rates are influenced by a combination of domestic factors such as agricultural output, fiscal policies, and monetary interventions, alongside external factors including crude oil prices, global economic conditions, and exchange rate fluctuations. By employing the NARDL approach, this study aims to uncover the asymmetric effects of exchange rate changes on inflation in India, offering valuable insights for policymakers and stakeholders. India is significantly reliant on imports for essential goods, making them susceptible to global price shocks (Amin et al., 2022). Therefore, managing inflation while ensuring currency stability becomes a critical challenge for policymakers in these countries. Traditional economic literatures often presuppose a symmetric relationship between exchange rates and inflation, implying that currency appreciations and depreciations have equal but opposite effects on inflation (Keefe & Shadmani, 2020). However, emerging empirical evidence suggests this relationship might be asymmetric. Specifically, currency depreciations could have a more substantial impact on inflation compared to appreciations (Widarjono et al., 2023). This asymmetry can be attributed to various factors, including the pricing behavior of firms, the structural composition of import and export markets, and the pass-through effect of exchange rates to domestic prices (Iormom et al., 2023). In economies with a high dependency on imports, currency depreciation can lead to a rise in import prices, thereby escalating inflation (Ndou & Gumata, 2017). On the other hand, currency appreciations might not result in a proportional decrease in inflation due to factors like price stickiness or the strategic pricing of imported goods by foreign suppliers (Ma, 2014).Identifying and understanding these asymmetric effects is essential for making effective monetary policies, enabling more targeted and precise interventions to stabilize the economy. This introduction sets the stage for an in-depth analysis of the asymmetric relationship between exchange rates and inflation in India, highlighting the relevance of using the NARDL approach to capture the complexities of this economic interaction.

2. Review of Literature

To understand the dynamic nature of macroeconomic variables, particularly the Real Effective Exchange Rate (REER) and inflation, we conducted a comprehensive literature review. This review aimed to develop a thorough understanding of these variables and assess the extent of their empirical examination.

REER is a measure of a country's exchange rate adjusted for differences in inflation rates between countries. Theoretically, a depreciation of the REER should lead to higher import prices and, subsequently, higher inflation (Dornbusch, 1980). On the other hand Inflation is defined as "a prolonged escalation in the overall price level" (Blanchard, 2017). Increased government spending can lead to higher inflation (Ferrara et al., 2021). A strong negative correlation exists between real effective exchange rate volatility and economic growth in OECD nations (Janus & Riera-Crichton, 2015). Real exchange rate shocks influence inflation dynamics in Ethiopia (Kayamo, 2021). A strong correlation exists between inflation and the real exchange rate (Achsani, 2010). Real depreciation positively affects inflation by increasing the money supply and improving the trade balance (Vinh & Fujita, 2007). The pass-through effect from exchange rates to prices is incomplete, meaning that changes in REER do not fully translate into changes in inflation (Taylor, 2001). The relationship between REER and inflation is also influenced by various factors, including monetary policy, trade openness, and economic growth (Bahmani-Oskooee et al., 2016).

On the basis of the above existing literatures we observed that most of these studies focus on examining the symmetrical relationship between these two macroeconomic variables. Despite this, the findings have been diverse, indicating an asymmetrical nature. Therefore, the present study aims to examine the asymmetrical relationship between exchange rates and inflation in India.

3. Data and Methodology

This study aims to explore the asymmetric relationship between exchange rates and inflation in India. The primary objectives include examining whether the impacts of exchange rate depreciations on inflation differ from those of appreciations, comparing the magnitude and direction of these effects, exploring the underlying economic mechanisms driving observed asymmetries, and providing policy recommendations based on the findings. To achieve these objectives, the study uses annual time series data from 1985 to 2022 using gross fiscal deficit (GFD), gross domestic product taken for the measure of economic growth (EG), imports (IM) including crude oil and non-oil, broad money supply (MS), the real effective exchange rate (REER) as the weighted average of a basket of 40 currencies, and inflation (INF) as represented by the consumer price index (CPI) to examine the cause-and-effect relationship between exchange rate and inflation. Furthermore, the data for the chosen variables has been sourced from the Handbook of Statistics on the Indian Economy, published by the Reserve Bank of India (RBI). The selection of these variables is grounded in both theoretical and empirical studies reviewed to date. However, it is important to note that other variables could potentially influence the dynamic nature of inflation. Given the scope of a single research paper, it is not feasible to include all possible variables.

Therefore, in the present research paper we concentrate, only those variables have been extensively used in the earlier literature.

3.1 Model Specification

Once the variables have been identified and data were gathered, the next step is determining the order of stationarity of the selected variables. This is achieved by employing the Augmented Dickey-Fuller test (ADF), as proposed by Dickey & Fuller (1979). To reinforce the robustness of the ADF findings, the Phillips-Perron (1989) test is also used. Based on the mixed order of stationarity obtained from the ADF and PP tests, the study opted to use the NARDL model. This decision has been taken because the model has a capability to handle non-linear relationships between variables and to separate the independent variable into its positive and negative partial sums. The specified long-run model is as follows:

$$\begin{aligned}\Delta(\mathrm{INF})_t = {} & \beta_0 + \sum_{i=1}^{p} \beta_{1i}\,\Delta(\mathrm{INF})_{t-1} + \sum_{i=1}^{p} \beta_{2i}\,\Delta\mathrm{LN}(\mathrm{GFD})_{t-1} + \sum_{i=1}^{p} \beta_{3i}\,\Delta\mathrm{LN}(\mathrm{EG})_{t-1} \\ & + \sum_{i=0}^{p} \beta_{4i}\,\Delta\mathrm{LN}(\mathrm{IM})_{t-1} + \sum_{i=0}^{p} \beta_{5i}\,\Delta\mathrm{LN}(\mathrm{MS})_{t-1} + \sum_{i=0}^{p} \beta_{6i}\,\Delta\mathrm{LN}(\mathrm{REER}^{+})_{t-1} \\ & + \sum_{i=0}^{p} \beta_{7i}\,\Delta\mathrm{LN}(\mathrm{REER}^{-})_{t-1} \\ & + \theta_1(\mathrm{INF})_{t-1} + \theta_2\mathrm{LN}(\mathrm{GFD})_{t-1} + \theta_3\mathrm{LN}(\mathrm{EG})_{t-1} + \theta_4\mathrm{LN}(\mathrm{IM})_{t-1} + \theta_5\mathrm{LN}(\mathrm{MS})_{t-1} \\ & + \theta_6\mathrm{LN}(\mathrm{REER}^{+})_{t-1} + \theta_7\mathrm{LN}(\mathrm{REER}^{-})_{t-1} \\ & + u_t \qquad (1)\end{aligned}$$

Equation (1) can be tested for the presence of an asymmetric relationship between inflation and exchange rate in both the long run $H_0: \beta^{+} = \beta^{-}$ and the short run

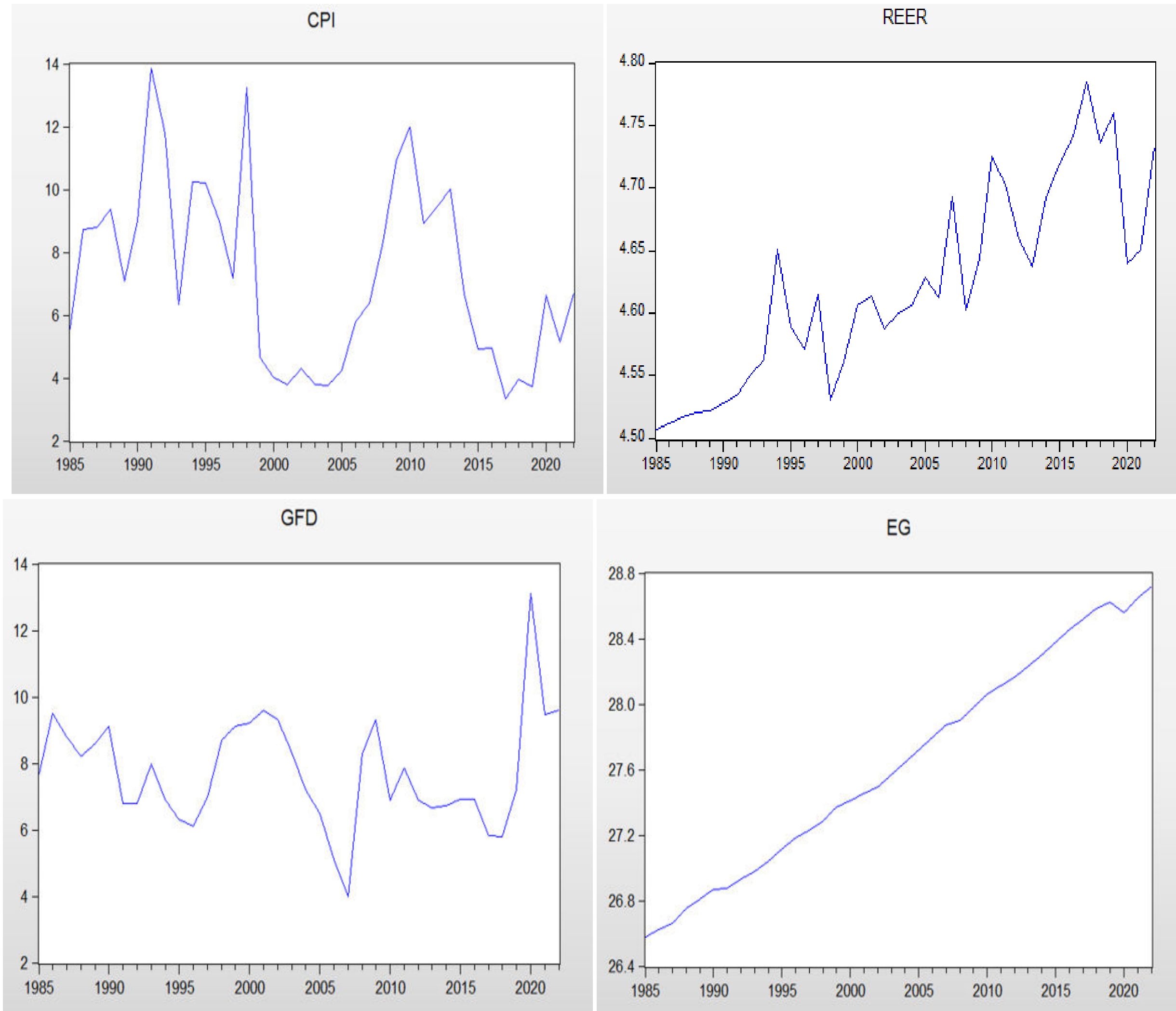
$H_0: D_i^+ = D_i^-$ using Wald test. To determine the presence of cointegration, we apply the "bounds testing" approach as suggested by Pesaran et al. (2001). This method involves evaluating joint significance using F-statistics and comparing them to two sets of critical values at different significance levels. If the computed F-statistic exceeds the upper bound critical value, it indicates the presence of cointegration among the variables. Conversely, if the F-statistic is below the lower bound critical value, it suggests no cointegration. If the F-statistic lies between the upper and lower bound critical values, the result is inconclusive. To determine the appropriate lag length for our analysis, we employ optimal lag order selection criteria. Once cointegration is confirmed, we formulate the Error Correction Model (ECM) to capture short-run dynamics and long-run adjustments as follows:

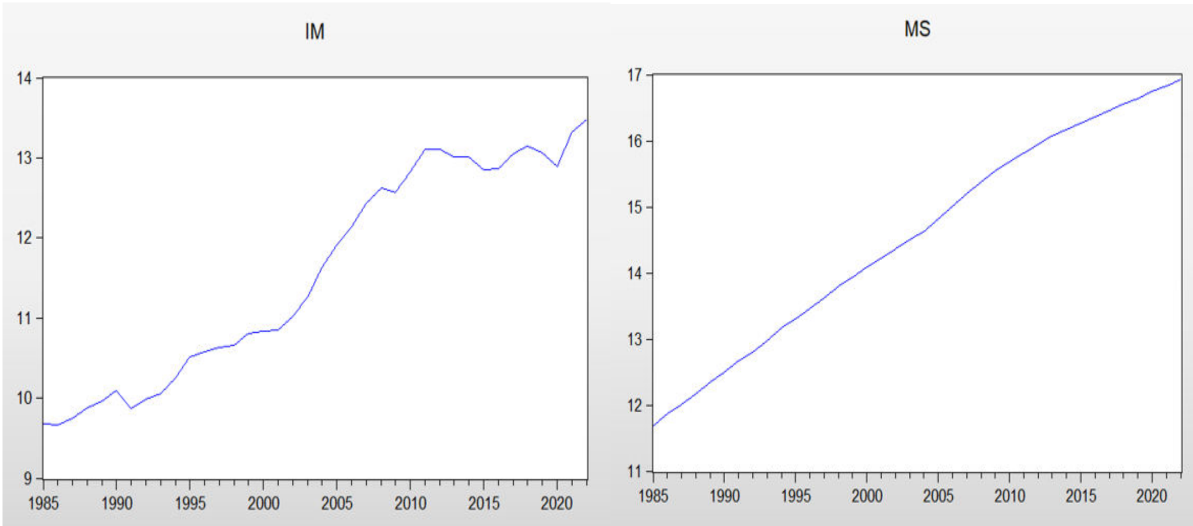
$$\Delta(\mathbf{INF})_t = \boldsymbol{\beta}_0 + \sum_{i=1}^{p} \boldsymbol{\beta}_{1i}\, \Delta(\mathbf{INF})_{t-1} + \sum_{i=1}^{p} \boldsymbol{\beta}_{2i}\, \Delta\mathbf{LN}(\mathbf{GFD})_{t-1} + \sum_{i=1}^{p} \boldsymbol{\beta}_{3i}\, \Delta\mathbf{LN}(\mathbf{EG})_{t-1} + \sum_{i=0}^{p} \boldsymbol{\beta}_{4i}\, \Delta(\mathbf{IM})_{t-1} + \sum_{i=0}^{p} \boldsymbol{\beta}_{5i}\, \Delta\mathbf{LN}(\mathbf{MS})_{t-1} + \sum_{i=0}^{p} \boldsymbol{\beta}_{6i}\, \Delta\mathbf{LN}(\mathbf{REER}^{+})_{t-1} + \sum_{i=0}^{p} \boldsymbol{\beta}_{7i}\, \Delta\mathbf{LN}(\mathbf{REER}^{-})_{t-1} + \boldsymbol{\lambda}\mathbf{ECT}_{t-1} + \mathbf{u}_t \quad (2)$$

4. Result and Discussion

In order to get a clear understanding of the raw data Figure 1 is presented. It shows that the variables GFD, EG, MS, and IM have positive trends over the sample period. However, both inflation and the real effective exchange rate exhibit fluctuations. Notably, the fluctuations in inflation are more than those in the real effective exchange rate, indicating greater instability in these two variables.

Figure 1
Time series plot of variables





Source(s): Prepared by authors using data from the Reserve Bank of India

Table 1
Descriptive Analysis

Statistics	INF	EG	GFD	IM	MS	REER
Mean	7.281362	27.64419	12.02582	11.56306	14.54013	102.0121
Std. Dev.	2.931509	0.669955	1.270724	1.333666	1.632233	8.070149
Skewness	0.463811	0.045169	0.203542	-0.028799	-0.161205	0.420986
Kurtosis	2.216102	1.708440	1.969324	1.371256	1.727945	2.187644
Jarque-Bera	2.335382	2.654124	1.944351	4.205529	2.726615	2.167330
Probability	0.311084	0.265255	0.378259	0.122118	0.255813	0.338353

Source: Author Calculation

Table 1 provides key statistical metrics for each variable, including INF, EG, GFD, IM, MS, and REER. These metrics indicate their average values, variability, distribution shapes, and normality based on the Jarque-Bera test. The p-values suggest that the data for all variables exhibit normality. Additionally, the skewness and kurtosis values reveal that most distributions have lighter tails and moderate asymmetries.

Table 2
Stationarity Result

Model with Constant Term [Level Form]			Model with Constant Term [First Difference Form]		
Variable	ADF (Prob.)	PP (Prob.)	Variable	ADF (Prob.)	PP (Prob.)
INF	0.0379**	0.0355**	REER	0.0000***	0.0000***
MS	-------	0.0259**	GFD	0.0000***	0.0000***
			EG	0.0000***	0.0000***
			IM	0.0005***	0.0005***
			MS	0.0337**	-----

This table represents the unit root test from the Augmented Dickey-Fuller (ADF) and Phillip-Peron (PP) tests. In both the tests, the variables INF is stationary at level form in constant term. On the other hand REER, GFD, EG, and IM are stationary at their first differences I(1). MS is stationary at level as well as at first difference. Note: ***Significance of 1 %, ** Significance of 5 %, and *Significance of 10 %,

Table 2 presents the stationarity results using the ADF and PP tests. INF is stationary at level I (0), while REER, GFD, EG, and IM are stationary at their first differences I (1). However, for MS, the PP test indicates stationarity at level I (0), whereas the ADF test suggests stationarity at the first difference I (1). This mixed order of integration supports the existence of a long-term relationship.

Table 3
Lag-Length Order Criteria

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-193.8888	NA	0.002679	11.10493	11.36885	11.19705
1	54.29939	399.8587 *	2.10e-08*	-0.683300*	1.164139 *	-0.038494*
2	89.41357	44.86812	2.62e-08	-0.634087	2.796870	0.563409

The VAR lag length order selection of all five criteria such as LR: sequential modified LR test statistic, FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion suggests a one lag. Note:***Significance of 1 %, ** Significance of 5 %, and *Significance of 10 %,

Before conducting further econometric analysis, the study determined the optimum lag length, as reported in Table 3. Pesaran & Shin (1998) recommend using a maximum of two lags for annual data. Following this statement, the NARDL specification (1, 0, 1, 1, 0, 1, and 1) was chosen based on the Akaike Information

Criterion, effectively capturing the dynamic relationships among the variables. The estimated results are reported in Table 3. The stationarity results (ADF and PP) provide the foundation for examining the long-run relationship among variables. The estimated outcomes, presented in the form of the bound test in panel (A) of Table 4, indicate that the F-statistics exceed both the lower and upper critical limits. This allows us to reject the null hypothesis of no cointegration and conclude that there are long-run relationships among the selected variables in both countries.

Table 4
Non-Linear ARDL Results

Panel (A) Bound Test			
F-statistic	I(0)	I(1)	**Decision**
	2.12	3.23	
	2.45	3.61	
	2.75	3.99	
5.89	3.15	4.43	Cointegration Exist

Panel (B) Long Run Estimates				
Variable	Coefficient	Standard Error	t-Statistics	P-value
$REER^{+}$	-0.305172	0.135585	-2.250785	0.0338
$REER^{-}$	0.340162	0.112018	3.036661	0.0057
GFD	10.41593	1.817445	5.731086	0.0000
EG	15.13388	8.727470	1.734051	0.0957
IM	7.095447	1.146959	6.186312	0.0000
MS	-12.66415	3.058641	-4.140450	0.0004

Panel (C) Long Run Asymmetric Test [Wald Test]		
t-Statistic	P-value	Conclusion
-3.839307	0.0008	Asymmetric Relation

Panel (D) Short-Run Dynamics				
Variable	Coefficient	Standard Error	t-Statistics	Prob.
$REER^{+}$	0.160518	0.101770	1.577256	0.1278
$REER^{-}$	-0.412457	0.108610	-3.797613	0.0009***
CointEq(-1)*	-0.776802	0.108205	-7.178992	0.0000***
R-Squared	0.71			
Adjusted R-Squared	0.66			
Prob.(F-statistic)	0.000000			

This table represents the NARDL bound test (F-Statistic) results and Wald test is performed on the null hypothesis that the coefficients of $REER^{+}$ and $REER^{-}$ are statistically not different. Further, long-run and short-run that effecton the dependent variable (INF).

After identifying the long-run relationship in the model, we analyzed the long-run coefficient values of positive and negative changes in REER along with GFD, EG, IM, and MS, and their impact on the dependent variable, INF. The positive and negative shocks of REER are statistically significant. Positive changes in REER (depreciation) are significant at the 5 percent level, while negative changes in REER (appreciation) are significant at the 1 percent level. The control variables, such as EG, GFD, IM, and MS, are also significant. However, the coefficient value of MS indicates that an increase in money supply leads to a decrease in INF. The negative association between MS and INF align with the finding of Abhinaya & Chaudhuri (2024). In contrast, GFD, EG, and IM exhibit a positive relationship with inflation in the long run. Specifically, a percentage increase in GFD leads to an increase in inflation, aligning with the findings of Akcay et al. (1996), who stated that higher deficits lead to higher inflation. Additionally, EG shows a weak association with inflation. Finally, IM exhibits a strong association with inflation, leading to the conclusion that a percentage increase in imports results in a 7.09 percent increase in inflation. This is because India remains highly dependent on crude oil to meet its needs, and the daily increase in oil product prices leads to higher inflation in the country, adversely impacting the overall economic condition.

As far as the REER is concerned it indicates that a 1% increase in positive changes in REER (depreciation) leads to a decrease in the INF by 0.30%. This outcome supports the finding of Ambachew et al. (2012) who indicated that the depreciation of the exchange rate decreases inflation. In contrast, a 1% decrease in negative changes in REER (appreciation) leads to a 0.34% decrease in INF. This suggests that appreciation has relatively more inflationary effects than depreciation in the long run. This outcome is opposite to the outcomes of Laryea & Sumaila (2001) and Loening et al.(2009).The larger impact of negative shockscompared to positive shocks clearly indicates that upswings and downswings do not adjust at the same pace, supporting the existence of a non-linear relationship between REER and INF.This non-linearity is statistically verified using the Wald test, as reported in panel (C) of Table 4. The results suggest rejecting the null hypothesis of long-run symmetry between the positive and negative components of REER, statistically proving the existence of an asymmetric relationship between REER and INF. Overall, the empirical results emphasize the significant impact of REER on INF. Furthermore, when comparing the inflationary situations between positive and negative shocks, it seems that negative shocks have more control over inflation than positive shocks.

The statistical summary of Equation (2),presented in the form of short-run dynamics along with an error correction term (ECT), is found in panel (D) of Table 4. The outcomes show that only negative changes in REER are significant in the short run. The coefficient sign suggests that a 1% decrease in REER leads to a 0.42% decrease in INF in the short run. However, the ECT is negative and significant, indicating the rate at which the variables readjust and revert to the long-run equilibrium level. The ECT value is -0.77, demonstrating that short-term disturbances are quickly rectified at a speed of 77% each year, as reported in panel (D) of Table 4.Furthermore, the model demonstrates strong explanatory power, as indicated by the R-squared and adjusted R-squared values of 71 % and 66 %, respectively. Additionally, the F-statistics (p-value) validate the overall adequacy of the model.

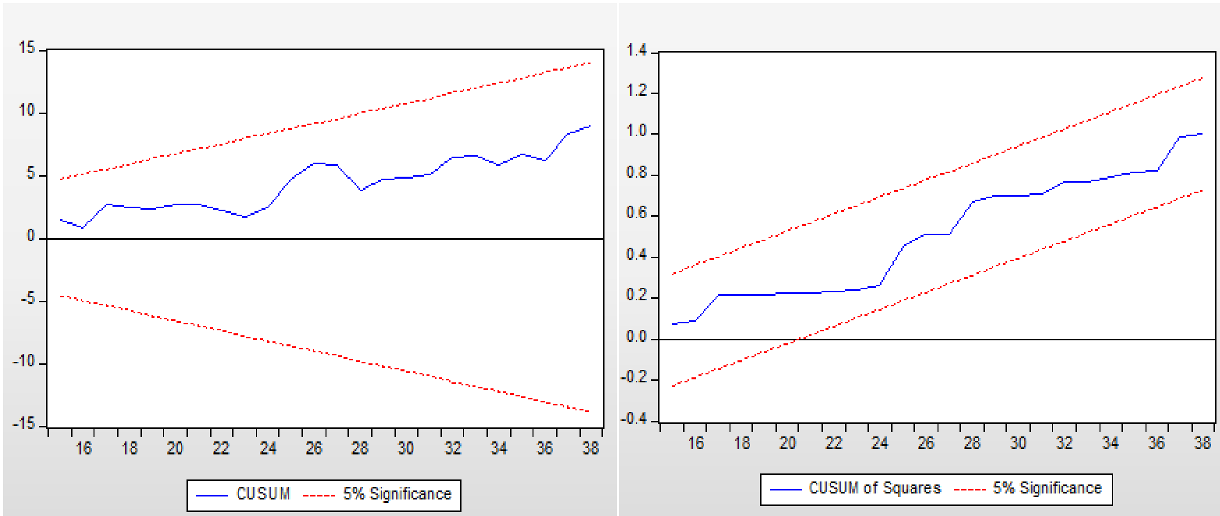
Table 5
Diagnostic Test

Test	**Test Name**	**P-value**
Serial Correlation	Breusch-Godfrey (LM Test)	0.26
Heteroskedasticity	ARCH (Test)	0.08
Specification Error	Ramsey RESET (Test)	0.21
Data Normality	Jarque-Bera (Test)	0.91

Source: Author Calculation

To assess the robustness of our model, diagnostic tests were conducted with the probability values provided in Table 5. The Breusch-Godfrey LM test results showed the model is free from serial correlation. Autoregressive conditional heteroscedasticity (ARCH) exhibits no conditional heteroscedasticity. The Ramsey RESET probability value confirmed that there is no specification error. Additionally, the Jarque-Bera test indicates that the data used in this model is normally distributed. These conclusions are supported by the respective p-values reported in Table 4. Finally, to test the stability of the model, we examined the graphs of the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). Both graphs lie within the 5% critical boundaries, indicating the overall stability of the model (see Figure 2).

Figure 2
CUSUM and CUSUMSQ Plot of NARDL Coefficients



Source: Author Calculation

5. Conclusion and Policy Implications

India has experienced attractive economic growth over the last decade, becoming the 5th largest economy in the world. However, with continued economic growth, moderate inflation has inevitably followed, as it is assumed that moderate inflation can enhance economic growth by mobilizing a country's resources. Over the past decade, India's inflation rate has been rising; creating pressure that harms many people's lives and reduces investor confidence, thereby discouraging productive investments.

This paper empirically investigates the asymmetric impact of the REER on INF using annual time-series data from 1985 to 2022. The empirical findings from the long-run and short-run NARDL models demonstrate that the REER is an important indicator to influence the inflationary situation in India. Other variables, such as GFD, EG, and IM, show a positive and significant impact on inflation. EG has a weak association with INF, while IM and GFD remains a major concern for policymakers. Contrary to classical economic theory, which suggests that an increase in money supply leads to higher price levels, the empirical findings indicate an opposite relationship, possibly due to the impact of the COVID-19 pandemic. The negative ECT provides evidence of convergence towards long-run equilibrium. The results clearly indicate that the main triggers of INF in India are exchange rate instability and import levels. Therefore, it is crucial to implement a tight monetary policy aimed at controlling the money supply and stabilizing the exchange rate market. To control INF, the Reserve Bank of India needs to ensure a stable exchange rate by attracting foreign private investment through macroeconomic policies that provide incentives for foreign investors. Implementing targeted foreign currency interventions by the central bank is crucial for managing and stabilizing the exchange rate. These interventions involve buying or selling foreign currencies to maintain the exchange rate within a specific range, which requires adequate foreign exchange reserves and clear intervention guidelines. Additionally, fiscal measures such as subsidies or temporary tax relief on essential goods and services can help mitigate the impact of external shocks. By targeting sectors like food and energy, these measures can be activated based on predefined criteria, such as international price increases exceeding certain thresholds. Effective coordination between government agencies is essential for timely implementation, ensuring stability amid global economic turbulence. Subsidizing costs or providing tax relief on essential goods not only alleviates immediate financial burdens on consumers but also helps stabilize price indexes and protects vulnerable populations from global economic disturbances. This strategy makes sure that the most vulnerable people remain safe from immediate financial difficulties, particularly in situations where external risks like shocks to the price of commodities are a possibility. However, research is an ongoing process, and results may vary due to changes in methodology, sample size, and area of the study.

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