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Determinants of the Indian Rupee–US Dollar Exchange Rate: A Regression Analysis of Macroeconomic Fundamentals, 2000–2025

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Abstract
This study examines the macroeconomic factors affecting the Indian Rupee vs US Dollar exchange rates over 2000–2025 using annual data. Influenced by purchasing power parity, uncovered interest rate parity, and the reserve-adequacy channel documented in the exchange-rate literature, four parameters are shortlisted: the India–US inflation differential, the India–US policy interest-rate differential, Brent crude oil prices, and India's foreign exchange reserves. As these series are non-stationary and not cointegrated, confirmed by Augmented Dickey–Fuller, KPSS, and Engle–Granger tests, a levels regression is rejected as spurious. The relationship is instead estimated using annual changes. The resulting model explains 55.1% of year-on-year exchange-rate variation (adjusted $R^2 = 0.461$, $F = 6.13$, $p = 0.002$) and passes all standard diagnostic checks. Changes in reserves and oil prices are significant predictors of rupee movements, while changes in inflation and interest-rate differentials are the kind of slow-burn relationships that a short annual dataset is not well equipped to catch. A simple levels regression on the same data produced a higher but spurious R^2 of 0.80, with an economically uninterpretable coefficient on reserves.

Keywords: exchange rate determination; cointegration; spurious regression; interest rate parity; purchasing power parity; foreign exchange reserves

1. Introduction

The Indian Rupee–US Dollar exchange rate is one of the most closely watched prices in the Indian economy, as it shapes import costs, export competitiveness, and the valuation of external debt and portfolio flows. After India's move to a managed float in the early 1990s, the rate has been mostly market-determined, though periodic RBI interventions aim to smooth volatility rather than defend a fixed level. This makes it a useful setting for testing standard exchange-rate theories, since capital controls and current-account vulnerability can make outcomes differ from textbook expectations.

Between 2000 and 2025 the rupee depreciated from roughly ₹45 to ₹87 per dollar, about 94% in nominal terms, across several distinct episodes: the mid-2000s capital-inflow boom, the 2008 global financial crisis, the 2013 'taper tantrum' that placed India among the so-called 'Fragile Five' emerging economies, the 2020 COVID-19 shock, and the 2022 global tightening cycle. This paper asks how much of that movement is explained by a set of standard macroeconomic fundamentals: relative inflation, relative interest rates, oil prices, and reserve buffers. Most studies on emerging-market exchange rates regress the exchange rate level on the levels of its determinants and stop at the resulting R^2 and coefficient significance. This specification fails once tested, because several of the series involved trend persistently rather than fluctuating around a stable mean. This study therefore moves in two stages: it first tests whether a levels regression can be trusted at all, and only then estimates and interprets the specification the data actually support.

2. Literature Review

Three theoretical pockets motivate the variables tested here.

2.1 Purchasing Power Parity and Interest Rate Parity

Relative purchasing power parity (PPP) predicts depreciation in currency value in proportion to the excess of domestic over foreign inflation. Rogoff (1996) documents the well-known 'PPP puzzle': deviations are large and persistent, and the pace of reversion is slow relative to how quickly nominal price shocks are believed to scatter. Coakley, Flood, Fuertes and Taylor (2005) show that PPP does hold on average across both developing and OECD panels, India included, over long horizons. Lothian (2016) reaches a similar conclusion, describing PPP as a long-run anchor rather than a short-run predictor. Taken together, these studies suggest that a 25-year annual sample, short by the standards of this literature, may simply not be long enough to pick up a PPP-consistent inflation effect.

On the interest-rate side, uncovered interest rate parity (UIP) links expected currency movements to interest differentials. Francis, Hasan and Hunter (2002) show this relationship strengthens with emerging-market financial liberalisation, a process India underwent substantially over the sample period studied here. For India specifically, Dua and Pandit (2002) establish, through cointegration and Granger causality, a genuine long-run relationship between domestic interest rates and external factors such as the forward premium and foreign interest rates. That paper is a useful methodological benchmark: rather than assuming a comparable long-run relationship holds for the exchange rate, the current study tests for it directly.

2.2 Oil Prices, Reserves, and Capital Flows

As India is heavily dependent on oil imports, crude prices are linked to the current account and the rupee. Ghosh (2011) and Tiwari, Dar and Bhanja (2013) both find a significant India oil–exchange rate relationship. Reboredo (2012) finds oil–FX co-movement is generally asymmetric and stronger for oil exporters than importers, using copula methods across a wider country set. Bal and Rath (2015) report bidirectional nonlinear causality between oil prices and the rupee; De Vita and Trachanas (2016), in a full published replication, show this result rests on an incorrect stationarity assumption about the oil-price series and does not hold once the correct order of integration is established, a directly relevant caution for the present study.

On the capital-flow front, Goyal and Sethi (2021) link Indian rupee volatility to portfolio flows and reserve movements, particularly around global risk-off episodes. Yildirim (2016) shows India's exchange rate co-moves with other 'Fragile Five' currencies through shared exposure to global risk shocks, rather than purely domestic fundamentals or a direct oil-import-cost channel.

2.3 Why Stationarity Testing Is Not Optional

A recurring methodological point in this literature is that trending macroeconomic series can produce a spuriously high R^2 and significant coefficients when regressed on one another in levels. Granger and Newbold (1974) established this formally; Engle and Granger (1987) show the levels regression is valid only if the series are cointegrated. Otherwise, the correct approach is to model stationary first differences instead. De Vita and Trachanas's (2016) India-relevant replication is an example of the cost of skipping this step.

3. Research Objectives

1. To examine whether standard exchange-rate theories — purchasing power parity, uncovered interest rate parity, and the reserve-adequacy channel — explain movements in the INR/USD exchange rate over 2000–2025.
2. To test, using appropriate stationarity and cointegration procedures, whether these relationships hold as a long-run equilibrium or only as short-run co-movement, and to identify which macroeconomic variables are the strongest correlates of annual rupee movements.

4. Research Methodology

4.1 Data

The study uses annual data for 2000–2025 (n = 26 levels; n = 25 first-differenced). The dependent variable is the annual average RBI reference rate in ₹ per US$ terms, from a unified long-run panel. Explanatory series are India CPI inflation (World Bank), the RBI repo rate and US federal funds rate (RBI DBIE; FRED), Brent crude oil, and India's foreign exchange reserves taken from the RBI Weekly Statistical Supplement. An India–US rate differential and the log of reserves are used as constructed variables. Annual data is used because reserves, inflation, and policy-rate series are only consistently available at yearly frequency for the earlier part of the sample; mixing frequencies across the period would create its own inconsistencies. The resulting 25 first-differenced observations is a real constraint on statistical power, and this is treated as a limitation of the study rather than something to work around, with its consequences discussed directly in Section 9.

Table 1. Annual macroeconomic data, India, 2000–2025

Year	USD/INR	Inflation (%)	Repo Rate (%)	Fed Funds (%)	Brent (US$/bbl)	Reserves (US$ bn)
2000	45.00	4.00	10.00	6.500	28.27	38.0
2001	47.22	3.80	8.50	1.750	24.42	46.4
2002	48.63	4.30	7.50	1.250	24.97	68.2
2003	46.59	3.80	7.00	1.000	28.85	99.5
2004	45.26	3.80	6.00	2.250	38.30	127.0
2005	44.00	4.20	6.25	4.250	54.43	132.0
2006	45.19	5.80	7.25	5.250	65.39	151.6
2007	41.18	6.40	7.75	4.250	72.70	247.5
2008	43.39	8.30	6.50	0.125	97.64	247.5
2009	48.33	10.90	4.75	0.125	61.86	279.1
2010	45.65	12.00	6.25	0.125	79.64	279.4
2011	46.58	8.90	6.75	0.125	110.94	296.7
2012	53.37	9.30	8.00	0.125	111.97	294.0
2013	58.51	10.90	7.75	0.125	108.86	292.0
2014	61.00	6.70	8.00	0.125	98.94	322.0
2015	64.11	4.90	6.75	0.375	52.37	350.0
2016	67.20	4.50	6.25	0.625	44.05	360.0
2017	65.12	3.60	6.00	1.375	54.39	410.0
2018	68.40	3.90	6.50	2.375	71.07	393.0
2019	70.42	3.73	5.15	1.625	64.03	433.0
2020	74.10	6.62	4.00	0.125	42.30	577.0
2021	73.92	5.13	4.00	0.125	70.44	633.0
2022	78.60	6.70	6.25	4.375	99.82	562.7
2023	82.60	5.65	6.50	5.375	82.62	620.9
2024	83.68	4.95	6.50	4.375	80.70	644.0
2025	87.16	2.40	5.25	3.625	69.04	692.0

4.2 Stationarity and Cointegration Testing

Every series is tested for a unit root (ADF) and, complementarily, for stationarity (KPSS) before any regression is estimated (Table 2). The ADF test is run with a trend term and automatic lag selection, and the KPSS test uses its matching trend-stationarity specification. The Engle–Granger cointegration tests in Table 3 follow the standard two-step approach: each pairing is regressed in levels and the residuals are then tested for a unit root, using critical values from MacKinnon (2010).

Table 2. Unit root tests on series levels (n = 26)

Series	ADF stat	ADF p-value	KPSS p-value	Stationary?
USD/INR	1.190	0.996	0.014	No
Inflation (CPI)	-1.469	0.549	≥ 0.100	Ambiguous
Interest rate differential	-1.440	0.563	≥ 0.100	Ambiguous
Brent crude oil (trend)	-1.697	0.752	—	No
ln(Forex Reserves) (trend)	-2.790	0.201	0.013	No

The Augmented Dickey–Fuller (ADF) test asks whether a series has a unit root; the KPSS test asks the opposite question. Running both together protects against either test's blind spots. Here, the exchange rate, oil prices, and reserves all show the trending, unit-root pattern typical of macroeconomic and financial series, which matters because two trending series can appear closely related purely because both are drifting upward over time, not because one causes the other. Inflation and the interest-rate differential are marked "ambiguous" because the ADF and KPSS results for them do not agree, so neither test gives a clean answer on its own. Rather than picking one test's verdict over the other, both are treated conservatively as non-stationary and carried into first differences along with the other two series, which is the safer choice when the two tests disagree.

USD/INR, Brent crude, and log reserves are each non-stationary in levels; a levels regression therefore risks the spurious-regression problem noted by Granger and Newbold (1974). Engle and Granger (1987) show this risk is avoided only if the series are cointegrated, sharing a common long-run trend. Table 3 reports Engle–Granger tests for each pairing and for the full system.

Table 3. Engle–Granger cointegration tests

Relationship tested	Statistic	p-value	Cointegrated?
USD/INR – Inflation	-0.476	0.966	No
USD/INR – Interest rate diff.	-0.910	0.919	No
USD/INR – Brent crude	0.428	0.992	No
USD/INR – ln(Reserves)	-1.015	0.900	No
Full 4-variable system	-2.420	0.136*	No

If two non-stationary series are cointegrated, a levels regression is not spurious; it estimates a genuine long-run equilibrium. The Engle–Granger test checks this by regressing one series on the other and testing whether the resulting residual is stationary. None of the pairings, nor the full system (test statistic –2.42), come close to clearing that bar, so no cointegrating relationship is found. With no cointegration established, a levels regression is rejected. First differences resolve the non-stationarity; the differenced exchange rate itself is borderline, and the model estimated is therefore:

$$\Delta(\text{USD/INR})_t = \beta_0 + \beta_1\Delta(\text{Inflation})_t + \beta_2\Delta(\text{Rate Diff.})_t + \beta_3\Delta(\text{Brent})_t + \beta_4\Delta\ln(\text{Reserves})_t + \varepsilon_t$$

This is in line with the differenced/returns-based UIP specifications used by Francis, Hasan and Hunter (2002) and follows Engle and Granger's (1987) prescribed remedy when cointegration cannot be established. As no cointegrating relationship exists among the levels, the model below describes short-run, year-on-year co-movement between the exchange rate and its determinants, not a long-run equilibrium level toward which the rupee reverts.

5. Data Analysis and Interpretation

5.1 Descriptive Statistics

Table 4 summarises annual changes over 2001–2025 (n = 25). The rupee depreciated by ₹1.69 per year on average, ranging from a ₹0.94 appreciation to a ₹5.29 depreciation.

Table 4. Descriptive statistics, annual changes (n = 25)

Variable (annual change)	Mean	Std. Dev.	Min	Max
Δ USD/INR (₹/US$)	1.69	1.79	-0.94	5.29
Δ Inflation (pp)	-0.02	3.30	-6.30	6.90
Δ Interest rate diff. (pp)	-0.13	1.16	-2.03	3.05
Δ Brent crude (US$/bbl)	1.79	20.63	-38.99	33.72
Δ ln(Forex Reserves)	0.078	0.089	-0.115	0.281

5.2 Regression Results

Table 5. First-differenced model regression results

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	3.218	0.537	5.989	<0.001 ***
Δ Inflation	0.270	0.240	1.123	0.275
Δ Interest Rate Diff.	0.164	0.304	0.540	0.595
Δ Brent Crude Oil	-0.078	0.022	-3.489	0.002 ***
Δ ln(Forex Reserves)	-11.849	2.937	-4.035	0.001 ***

Table 5 presents the first-differenced model, which is jointly significant ($F = 6.13$, $p = 0.002$) and explains 55.1% of year-on-year exchange-rate variation with adjusted $R^2 = 0.461$. Among the four predictors, only the changes in reserves and Brent crude are significant at the 1% level; the change in inflation and the interest-rate differential are not significant.

The reserves coefficient (–11.85, $p = 0.001$) suggests years of faster reserve accumulation coincide with rupee appreciation, a more economically meaningful result than the levels-model coefficient. The Brent coefficient (–0.078, $p = 0.002$) is also negative, implying rupee strength in years of rising oil prices, contrary to the standard import-cost channel. This result is consistent with Yildirim (2016), who attributes it to oil rallies coinciding with risk-on capital inflows into emerging markets like India that dominate the direct cost effect within the same year. This capital-flow channel can outweigh the trade-cost channel because portfolio inflows and reserve accumulation tend to rise during the same global growth upswings that also push oil demand higher. This annual net effect should be read as evidence of that offsetting dynamic, not as a claim that the import-cost channel does not exist. Both coefficients should be read as descriptions of average co-movement across 2001–2025, rather than as stable structural parameters suitable for out-of-sample forecasting.

5.3 Diagnostic Tests

Variance Inflation Factor (VIF) flags predictors that overlap so much the model cannot tell their individual effects apart; values above ~5 are a concern, and everything here is close to 1, so there is no meaningful overlap.

The Breusch–Pagan test checks for heteroskedasticity, errors that grow or shrink systematically across the sample, which would make the reported standard errors unreliable. A high p-value of 0.65 here means no such problem is detected.

The Durbin–Watson statistic ranges from 0 to 4, with 2 meaning 'no pattern', and checks whether a model's errors are correlated with the previous period's error. A score far from 2 signals a mis-specified or spurious model; the original levels model's score of 0.65 was one such signal. A score of 1.97 here is essentially a clean model.

Table 6. Variance inflation factors

Variable	VIF
Δ Inflation	1.00
Δ Interest Rate Diff.	1.07
Δ Brent Crude Oil	1.10
Δ ln(Forex Reserves)	1.06

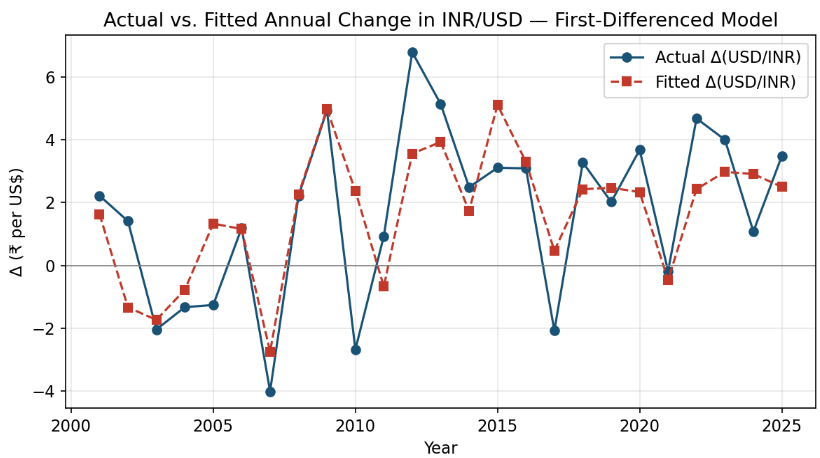

Figure 1. Actual vs. fitted annual change in INR/USD

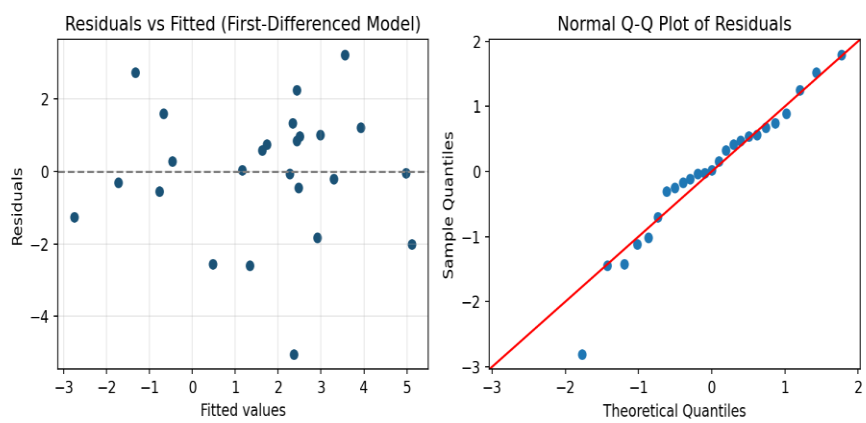

Figure 2. Residual diagnostics: residuals vs. fitted (left), normal Q-Q plot (right)

6. Results and Discussion

Three findings connect back to the literature reviewed in this study.

First, the study itself illustrates Granger and Newbold's (1974) warning directly. An initial levels regression on this data looked more impressive, with an R^2 of 0.77–0.81, but failed cointegration testing. It carried a reserves coefficient that reflected two trending series moving together rather than any genuine economic link, in line with the same failure mode De Vita and Trachanas (2016) documented.

Both the original levels model and Bal and Rath's (2015) result looked entirely logical on the standard of a high R^2 and significant t-statistics, but only after formal stationarity and cointegration testing was the problem identified.

Second, once correctly specified in first differences, foreign exchange reserves and oil prices are the robust short-run correlates of rupee movements, while inflation and interest-rate effects are not detectable at annual frequency. This is consistent with the literature: Rogoff (1996) and Lothian (2016) both treat PPP as a long-run anchor rather than a short-run influence. Coakley, Flood, Fuertes and Taylor (2005) find that even where PPP holds, the speed of reversion toward it is often too slow to detect with a sample as short as 25 annual observations. Francis, Hasan and Hunter (2002) find a similar pattern for UIP, which holds only partially and whose strength varies by country even after emerging markets liberalised their financial systems, consistent with the weak, statistically insignificant interest-rate-differential coefficient found here. The absence of a significant result for either channel should not be read as evidence against the theories themselves; instead, it reflects a limitation of annual-frequency data relative to the horizon over which these theories are expected to operate.

Third, consider the negative oil-price coefficient: rupee strength coincides with rising oil prices within the same year. This is well explained by the global risk-appetite channel that Yildirim (2016) documents for the Fragile Five economies, including India — oil rallies have often coincided with periods of strong global growth that also bring risk-on capital inflows to emerging markets, and within the same calendar year these inflows outweigh the direct current-account drag from a larger import bill. This finding is consistent with Reboredo (2012), who shows that oil–exchange rate co-movement is asymmetric and regime-dependent, and with Tiwari, Dar and Bhanja (2013), whose wavelet-based analysis finds that the India oil–exchange rate relationship is time- and frequency-varying rather than fixed. Both studies caution against reading a single annual-frequency coefficient as evidence of a stable, mechanical oil-to-rupee channel; the results reported here describe co-movement over the sample period, not a causal, forecastable mechanism.

7. Practical / Managerial Implications

For policymakers, the results suggest that RBI reserve positioning and global oil-price developments are more immediately relevant to short-run rupee movements than domestic inflation or interest-rate settings, and merit close monitoring for near-term exchange-rate risk. Exporters and importers may find reserve trends and oil-price momentum more useful early indicators of annual rupee direction than inflation differentials alone. Investors and treasury managers should treat PPP- and UIP-based fair-value estimates as long-run anchors rather than short-term trading signals, given how slowly those relationships assert themselves in the data.

8. Conclusion

An initial levels regression of the INR/USD rate on inflation, interest-rate, oil-price, and reserve differentials produced a superficially strong fit (R^2 of 0.77–0.81) but failed formal cointegration testing and was rejected as spurious. Re-estimated in first differences, as Engle and Granger (1987) prescribe, the model passes all standard diagnostics and identifies reserve growth and oil-price changes as significant, economically interpretable short-run correlates of rupee movements, while PPP- and UIP-implied effects are not detectable at annual frequency.

Taken together, the evidence suggests that USD/INR movements over 2001–2025 are driven less by inflation and interest-rate differentials and more by reserve dynamics and global oil-price-linked capital flows. This does not mean PPP and UIP are false; rather, as the literature reviewed here suggests, they operate over horizons longer than this sample can detect. What this paper identifies instead is the short-run reality: in any given year, the rupee's movement against the dollar has tracked the RBI's reserve position and shifts in global risk appetite tied to oil markets far more closely than it has tracked conventional price- and interest-based fundamentals.

Beyond its substantive findings, the paper's main contribution is methodological: a transparent, fully diagnosed demonstration of why stationarity and cointegration testing is a precondition for valid inference in exchange-rate regressions, not an optional check.

9. Limitations of the Study

1. **Short-run only.** With no cointegration found, the results describe short-run co-movement, not a long-run equilibrium level for the rupee.

2. **Small sample.** The 25 annual changes limit the test's power. This shows up in the borderline unit-root result for ΔUSD/INR.
3. **Omitted variables.** Portfolio and FDI flows, the current account, and global risk indices (VIX, DXY) are not included, mainly because consistent annual data across the full 2000–2025 period is not readily available without combining different data sources.
4. **Model design.** The model is contemporaneous, linear, and single-equation, and does not account for possible reverse causality (e.g., RBI reserve management responding to exchange-rate pressure).

10. Future Research Directions

1. **Longer sample.** A longer sample revealing cointegration would support a Vector Error Correction Model, as used by Dua and Pandit (2002) for Indian interest rates.
2. **Higher frequency.** Moving to monthly or quarterly data would improve test power and make it feasible to include portfolio flows, the current account, and global risk indices such as VIX and DXY.
3. **Structural modelling.** A structural VAR, as used by Yildirim (2016), could address reverse causality and the time-varying dynamics documented by Tiwari, Dar and Bhanja (2013).

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