

Crude Oil Price Shocks and the Indian Rupee–US Dollar Exchange Rate Evidence from a Nonlinear ARDL Model

Cinoj George

Faculty of Health Sciences, Girne American University, Kyrenia, Cyprus

Abstract

This study examines whether increases and decreases in international crude-oil prices are associated differently with the Indian rupee–US dollar exchange rate. Monthly data from January 2006 to April 2021 combine INR per US dollar, Brent crude oil, a broad trade-weighted US dollar index, and the India–United States short-term interest-rate differential. A nonlinear autoregressive distributed lag model decomposes log Brent changes into positive and negative partial sums and separates impact dynamics from conditional long-run responses. Bayesian-information-criterion selection yields a parsimonious NARDL(1,0) error-correction specification. The bounds statistic ($F = 2.222$) lies below the 10% lower bound for four regressors; consequently, the data do not establish a stable level relationship and conditional long-run coefficients are not interpreted as confirmed cointegrating effects. The error-correction loading is negative (-0.0785 , $p = 0.0039$), but this does not override the bounds decision. Contemporaneous oil-increase and oil-decrease terms are individually insignificant, and the short-run symmetry restriction is not rejected ($F = 0.199$, $p = 0.656$). A conditional equality test for level oil components is rejected ($F = 4.865$, $p = 0.029$), but its economic interpretation remains provisional without bounds cointegration. Broad dollar movements dominate monthly USD/INR changes. The results show why nonlinear modelling adds diagnostic value even when asymmetry is not robustly established: it prevents an unsupported symmetric long-run narrative and identifies where evidence is conditional. Implications concern reserve management, oil-import hedging, and cautious use of nonlinear exchange-rate models.

Keywords: Crude oil prices; USD/INR exchange rate; NARDL; asymmetric adjustment; India

1 Introduction

India's dependence on imported crude oil makes the rupee sensitive to the external price of energy. A rise in the dollar price of crude can enlarge the import bill, increase the demand for foreign currency, worsen the trade balance, lift domestic inflation expectations, and alter expected monetary policy. Each channel can raise INR per USD, which denotes rupee depreciation in this study. Oil-price declines can work in the opposite direction, but the magnitudes need not mirror one another. Import contracts, retail-price rigidities, inventory adjustment, hedging, capital-flow reactions and Reserve Bank of India intervention can delay or attenuate favourable shocks while adverse shocks are priced rapidly.

A linear ARDL imposes the same slope, with opposite sign, on increases and decreases in oil prices. The NARDL construction of Shin et al. [1] relaxes that restriction by decomposing oil changes into positive

and negative partial sums. It allows impact coefficients, lagged adjustment, conditional long-run coefficients and dynamic multipliers to differ by shock direction. This is a substantive financial-dynamics question rather than a search for significance.

The central question is whether increases and decreases in Brent crude prices affect USD/INR differently in the short run and long run. Secondary questions ask whether a level relationship exists; how each oil component enters; whether short- and long-run symmetry restrictions hold; how quickly disequilibrium is corrected; what roles broad dollar strength and the bilateral short-rate differential play; and whether the nonlinear specification reveals information hidden by symmetry.

The contribution is threefold. First, the paper applies an explicit asymmetric adjustment model to a major oil-importing economy. Second, it distinguishes a bounds-test decision from the statistical significance of an error-correction loading, thereby avoiding a common over-interpretation. Third, it reports nonlinear multipliers and robustness specifications under an information set frozen at 30 June 2021.

2 Literature Review and Theoretical Background

2.1 Oil prices and exchange rates

The terms-of-trade channel predicts different exchange-rate responses for oil exporters and importers. For an importer, costlier oil transfers income abroad and can weaken the trade balance; for an exporter, the wealth transfer can support the currency. Portfolio rebalancing may transmit oil receipts into dollar assets, while inflation and monetary-policy responses alter real interest differentials. Empirical studies document economically meaningful links whose sign and persistence depend on country structure and model design [2]–[6].

2.2 Importers, exporters and India

Cross-country evidence cautions against a universal coefficient. Reboredo [7] finds dependence that can vary across market states, and Turhan et al. [8] show that emerging-market currencies respond to oil-price movements. For India, Ghosh [9], Tiwari et al. [10], and Jain and Ghosh [11] connect oil prices with the rupee and other Indian asset prices using linear, causality or time-frequency approaches. These studies motivate the relationship but do not make short- and long-run sign asymmetry the sole organizing restriction.

2.3 Linear versus nonlinear evidence

Symmetric models can average together fast depreciation after adverse oil shocks and slower appreciation after favourable shocks. Such averaging may conceal adjustment costs, price stickiness, policy intervention and state-dependent capital flows. NARDL is useful because OLS estimation remains possible while the level and differenced coefficients for positive and negative partial sums are separately identified [1]. Dynamic multipliers then trace the transition from impact to the conditional steady state.

2.4 Research gap

Evidence available by 30 June 2021 is extensive on oil–currency linkages but comparatively limited in separating both short-run and long-run Brent asymmetry for USD/INR within one coherent NARDL system. The gap is framed as limited evidence, not the absence of prior work. A further need is to evaluate whether an asymmetric interpretation survives cointegration testing when the sample includes the unusual 2020 oil and foreign-exchange environment.

2.5 Conceptual framework

Positive Brent shock → larger import bill, dollar demand, inflation and risk premia → possible rupee depreciation. Negative Brent shock → smaller import bill and inflation pressure → possible appreciation, moderated by pass-through lags, administered pricing, reserve accumulation and capital-flow conditions. Broad dollar strength directly raises bilateral dollar pressure, while the India–US interest differential may attract capital toward rupee assets or proxy relative monetary conditions. Unequal adjustment costs and policy responses imply that the positive and negative oil coefficients need not be equal.

2.6 Hypotheses

H01: positive oil-price shocks have no significant conditional long-run effect on USD/INR. H02: negative oil-price shocks have no significant conditional long-run effect. H03: positive and negative oil-price shocks have symmetric conditional long-run effects. H04: their short-run effects are symmetric. H05: no level relationship exists among USD/INR, the oil components and controls. H06: the equilibrium-correction coefficient is not negative and significant.

3 Data and Methodology

3.1 Data, transformations and cutoff rule

The analysis uses only secondary data. Daily Brent and broad-dollar observations are averaged within calendar months; already-monthly exchange-rate and interest-rate series are retained. The common sample is January 2006–April 2021 (184 aligned observations). April is chosen conservatively: all inputs were observable before 30 June 2021, whereas using June would mix a still-incomplete month with macroeconomic series released on different schedules. The 2006 start is dictated by the broad dollar index. Logarithms are used for positive-valued price and index series. The interest differential is measured in percentage points.

Table 1 Variable definitions and sources

Symbol	Definition and unit	Transformation	Source and cutoff rationale
lnE	Monthly INR per USD; increase = rupee depreciation	Natural log	Federal Reserve Bank of St. Louis FRED EXINUS [20]; April 2021 retained
lnO	Europe Brent spot price, USD/barrel	Daily mean to month; natural log	US Energy Information Administration via FRED DCOILBRENTU [21]; daily April observations available in May 2021
O+ / O−	Positive/negative cumulative Brent log changes	Partial sums	Constructed from lnO following Shin et al. [1]

lnD	Trade-weighted US dollar index, broad goods and services	Daily mean to month; natural log	Board of Governors via FRED DTWEXBGS [22]; begins 2006
R	India short-term interbank rate minus US federal funds rate, percentage points	Monthly difference	OECD/Main Economic Indicators via FRED IRSTCI01INM156N [23] and Board of Governors FEDFUNDS [22]

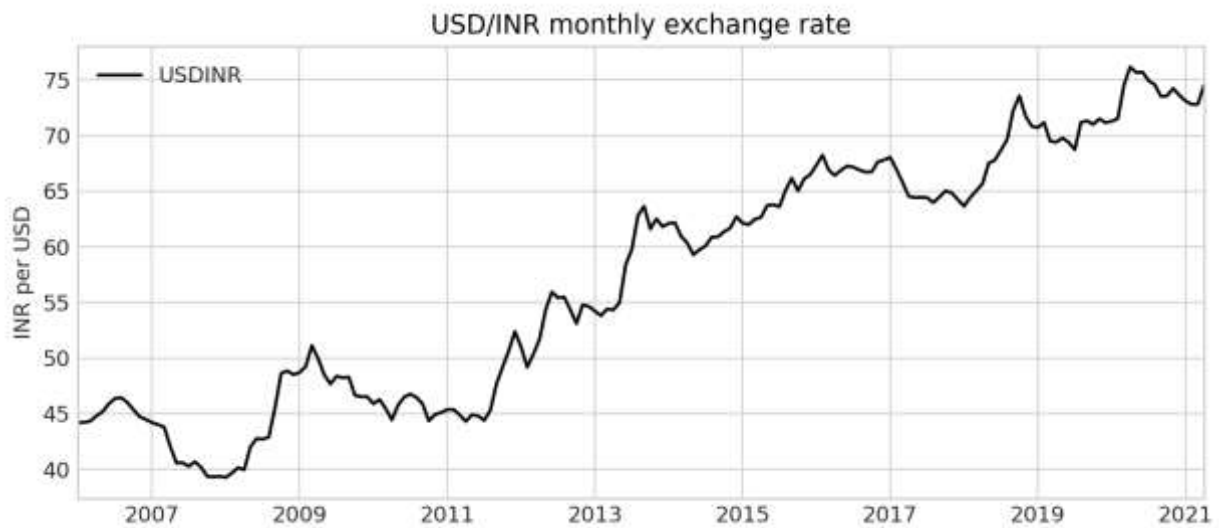


Figure 1 USD/INR exchange-rate evolution

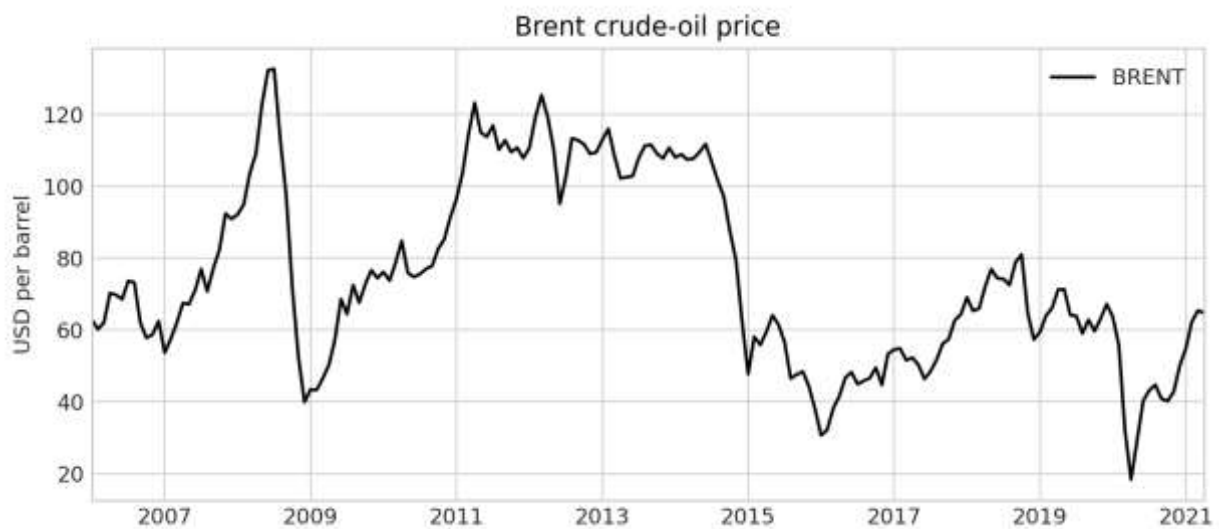


Figure 2 Brent crude-oil price evolution

3.2 Model

$$\ln E_t = \alpha_0 + \alpha_1 \ln O_t + \alpha_2 \ln D_t + \alpha_3 R_t + u_t \quad (1)$$

$$O_t^+ = \sum_{j=1}^t \max(\Delta \ln O_j, 0); \quad O_t^- = \sum_{j=1}^t \min(\Delta \ln O_j, 0) \quad (2)$$

$$\Delta \ln E_t = c + \rho \ln E_{t-1} + \theta^+ O_{t-1}^+ + \theta^- O_{t-1}^- + \theta_D \ln D_{t-1} + \theta_R R_{t-1} + \sum \varphi_i \Delta \ln E_{t-i} + \sum (\pi_j^+ \Delta O_{t-j}^+ + \pi_j^- \Delta O_{t-j}^- + \delta_j \Delta \ln D_{t-j} + \gamma_j \Delta R_{t-j}) + \varepsilon_t \quad (3)$$

The conditional long-run coefficients are $\beta^+ = -\theta^+/\rho$ and $\beta^- = -\theta^-/\rho$. Long-run symmetry is tested by $H_0: \theta^+ = \theta^-$; short-run symmetry is $H_0: \sum \pi^+ = \sum \pi^-$. A positive coefficient raises INR per USD and therefore denotes rupee depreciation. Dynamic multipliers are $m_h^+ = \sum_{j=0}^h \partial \ln E_{t+j} / \partial O_t^+$ and m_h^- analogously, converging to β^+ and β^- only when a stable level relationship is supported.

3.3 Estimation and decision rules

Data are aligned without interpolation. Descriptive and correlation evidence precede ADF screening using the procedure in [13]. The ARDL bounds framework admits I(0)/I(1) mixtures but excludes I(2). Lag orders from one to four for the dependent variable and zero to three for regressors are compared by BIC; the selected conditional ECM is then estimated by OLS. The bounds F statistic is compared with Pesaran et al. [12], unrestricted intercept/no trend, $k = 4$: at 10%, $I(0) = 2.45$ and $I(1) = 3.52$; at 5%, 2.86 and 4.01; at 1%, 3.74 and 5.06. Values below the lower bound reject a level relation, between bounds are inconclusive, and above the upper bound support one. Diagnostics include the Breusch–Godfrey serial-correlation test [14], [15], the Breusch–Pagan heteroskedasticity test [16], the Jarque–Bera normality test [17], and Ramsey RESET [18]. Parameter stability follows the recursive-residual approach of Brown et al. [19]. COVID-19 is treated as a possible disturbance, not a replacement research question.

4 Empirical Results

Table 2 Descriptive statistics

Variable	N	Mean	Median	SD	Min	Max	Skew	Kurtosis
LUSDINR	184	4.0270	4.0901	0.1996	3.6704	4.3329	-0.188	1.587
LBRENT	184	4.2592	4.2488	0.3605	2.9112	4.8882	-0.374	3.015
LDOLLAR	184	4.6165	4.5851	0.1022	4.4580	4.8145	0.206	1.541
INTDIFF	184	5.5037	5.8150	2.4583	0.7400	10.1700	-0.286	2.428

Table 3 Correlation matrix

	LUSDINR	OILPOS	OILNEG	LDOLLAR	INTDIFF
LUSDINR	1.000	0.917	-0.934	0.837	0.328
OILPOS	0.917	1.000	-0.984	0.732	0.284
OILNEG	-0.934	-0.984	1.000	-0.824	-0.216
LDOLLAR	0.837	0.732	-0.824	1.000	-0.123
INTDIFF	0.328	0.284	-0.216	-0.123	1.000

Table 4 ADF unit-root tests

Variable	Form	ADF statistic	Lag	N	Decision
LUSDINR	level	-0.663	1	182	Do not reject
LUSDINR	first difference	-9.618	0	182	Reject at 1%
OILPOS	level	0.457	1	182	Do not reject
OILPOS	first	-9.845	0	182	Reject at 1%

	difference				
OILNEG	level	0.113	1	182	Do not reject
OILNEG	first difference	-7.717	0	182	Reject at 1%
LDOLLAR	level	-1.259	1	182	Do not reject
LDOLLAR	first difference	-8.488	0	182	Reject at 1%
INTDIFF	level	-1.608	2	181	Do not reject
INTDIFF	first difference	-9.399	1	181	Reject at 1%

Table 5 Lag-selection results

p	q	AIC	BIC
1	0	-1542.13	-1510.03
2	0	-1540.11	-1504.87
3	0	-1528.76	-1490.38
2	1	-1534.78	-1486.72
1	1	-1529.45	-1484.60
4	0	-1518.75	-1477.24
3	1	-1523.28	-1472.11
2	2	-1519.81	-1459.04

Table 6 Bounds test for a level relationship

F statistic	k	10% I(0)	10% I(1)	Decision
2.222	4	2.45	3.52	No level relationship at 10%

Table 7 Conditional long-run NARDL coefficients

Regressor	Coefficient	Delta-method SE	t
OILPOS	0.2187	0.0859	2.547
OILNEG	0.1719	0.0941	1.826
LDOLLAR	1.4453	0.4526	3.193
INTDIFF	0.0212	0.0071	2.984

Table 8 Short-run and error-correction estimates

Term	Coefficient	SE	t	p
const	-0.22871	0.18750	-1.220	0.2242
LUSDINR_L1	-0.07852	0.02683	-2.927	0.0039
OILPOS_L1	0.01717	0.00774	2.218	0.0278
OILNEG_L1	0.01350	0.00795	1.697	0.0915
LDOLLAR_L1	0.11348	0.05524	2.054	0.0415

INTDIFF_L1	0.00167	0.00084	1.992	0.0479
dOILPOS_0	0.02821	0.02451	1.151	0.2513
dOILNEG_0	0.01360	0.01645	0.827	0.4094
dLDOLLAR_0	0.86342	0.09635	8.961	0.0000
dINTDIFF_0	0.00650	0.00415	1.567	0.1190

Table 9 Wald asymmetry tests

Restriction	F	p	Decision
Conditional level: $O^+ = O^-$	4.865	0.029	Reject at 5%, conditional
Short run: $\Sigma \Delta O^+ = \Sigma \Delta O^-$	0.199	0.656	Do not reject

Table 10 Diagnostic tests

Test	Statistic	p	Conclusion
Breusch–Godfrey LM(12)	14.677	0.839	No serial correlation
Breusch–Pagan LM	13.874	0.127	No heteroskedasticity
Jarque–Bera	12.284	0.002	Reject normality
Ramsey RESET	0.499	0.481	No functional-form rejection

Table 11 Robustness across lag specifications

Model	N	AIC	BIC	R ²	Level-symmetry F	p
BIC NARDL	183	-1542.1	-1510.0	0.417	4.865	0.029
NARDL q=1	182	-1529.5	-1484.6	0.433	4.577	0.034
NARDL q=2	181	-1514.0	-1456.5	0.439	4.728	0.031
NARDL p=2 q=1	182	-1534.8	-1486.7	0.455	5.401	0.021

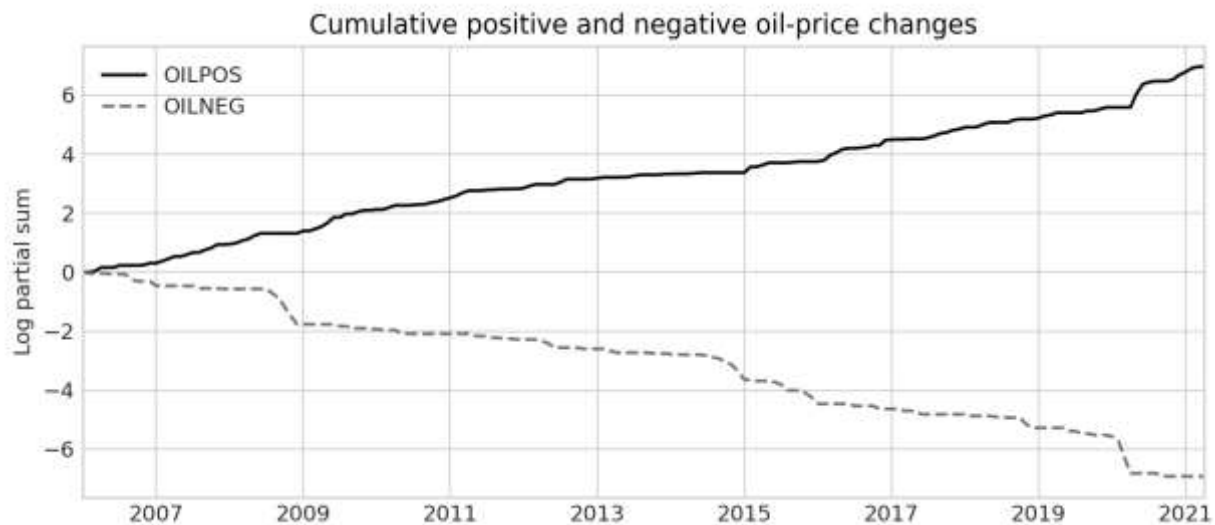


Figure 3 Positive and negative cumulative log-oil changes

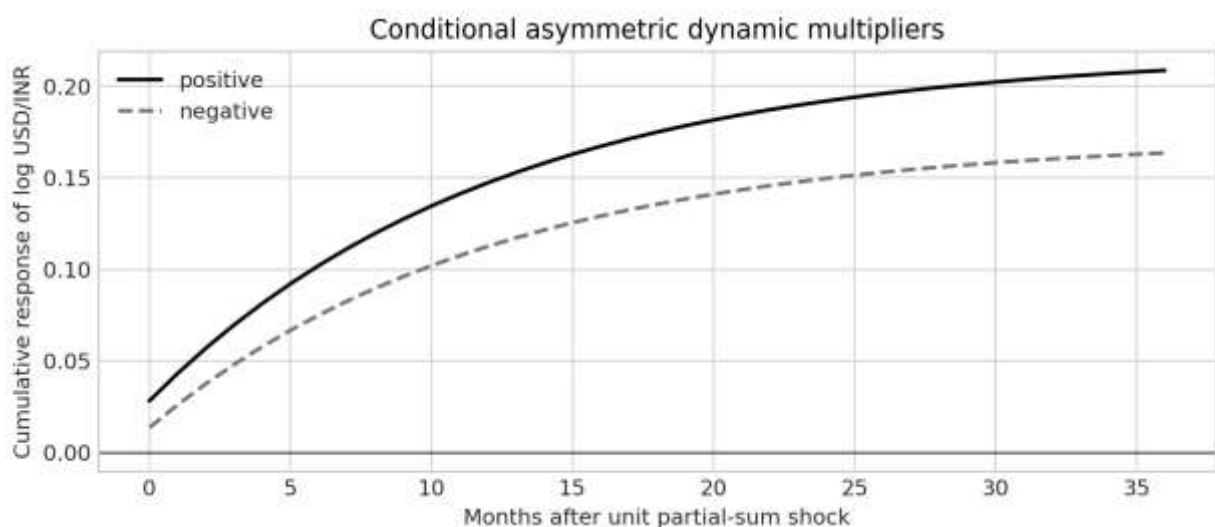


Figure 4 Conditional asymmetric dynamic multipliers

The selected NARDL(1,0) explains 41.7% of monthly log-exchange-rate changes. The oil impact coefficients are positive but individually insignificant: 0.0282 for positive changes and 0.0136 for negative changes. Because O^- itself takes negative increments, a positive coefficient on ΔO^- implies appreciation following an oil-price fall. Their equality is not rejected. By contrast, the contemporaneous broad-dollar elasticity is 0.8634 ($p < 0.001$), indicating that international dollar conditions dominate within-month bilateral movement.

The loading on lagged $\ln E$ is -0.0785 , implying a conditional half-life of about 8.5 months [$\ln(0.5)/\ln(1-0.0785)$]. Its sign and significance are compatible with correction, but the joint bounds statistic does not validate a stable level system. The conditional ratios in Table 7 and multiplier paths in Figure 4 must therefore be read as model-implied diagnostics, not confirmed long-run causal effects. Residual serial correlation, heteroskedasticity and RESET misspecification are not detected, while normality is rejected, consistent with exceptional financial observations in the sample.

5 Discussion

The central finding is disciplined non-confirmation. Monthly Brent increases and decreases do not produce statistically distinguishable impact responses in USD/INR, and the joint levels test does not support cointegration. This differs from a mechanical narrative in which India's import dependence necessarily creates a stable oil elasticity. The result is nevertheless compatible with the economic channels: the import-bill effect may be offset or delayed by hedging, reserve operations, administered domestic prices, expectations and capital flows. Broad global dollar movements have a much clearer contemporaneous association.

The conditional level coefficients are economically sizeable—a 1% accumulated positive oil movement corresponds to about 0.219% higher USD/INR in the fitted steady state, compared with 0.172% for the negative component—but those magnitudes cannot be promoted to established long-run effects after the bounds decision. The conditional Wald rejection says the imposed symmetric slope is questionable inside this specification; it does not rescue cointegration. This distinction is the principal nonlinear modelling insight.

The evidence partly aligns with Indian studies reporting oil–rupee interaction [9]–[11] but is more guarded about persistence. Differences can arise from frequency, endpoint, controls, crisis observations and whether symmetry is imposed. The 2020 disruption plausibly contributes to non-normality and parameter strain, yet it is not interpreted with information unavailable on 30 June 2021.

6 Conclusion and Policy Implications

For January 2006–April 2021, the preferred NARDL does not establish a cointegrating level relationship between Brent components and USD/INR. Short-run oil symmetry is not rejected. A conditional difference between positive and negative level components appears, but it is provisional. The most robust empirical association is the strong contemporaneous response of USD/INR to broad US dollar strength.

The Reserve Bank of India should therefore avoid treating a single oil elasticity as a sufficient exchange-rate rule. Reserve planning and stress tests can distinguish adverse and favourable oil scenarios while jointly conditioning on the global dollar. Oil importers and corporate treasurers may use asymmetric scenarios for hedge design, but the estimates do not identify an optimal hedge ratio. Energy-security measures that reduce import exposure can lower one source of external vulnerability, although the model does not establish the welfare ranking of policies. Portfolio investors should separate oil news from global dollar and interest-rate conditions.

Limitations include aggregate monthly data, benchmark dependence, a broad-dollar proxy, possible revisions to macroeconomic series, structural change, non-normal shocks, a common-lag restriction, and absence of causal identification. The sample ends before 30 June 2021 to respect release timing. Future work, viewed from that date, could use vintage-controlled data, break-augmented bounds tests, quantile NARDL, regime switching, nonlinear causality, time-varying parameters, higher-frequency identification and comparisons among oil-importing emerging economies.

References

1. Y. Shin, B. Yu, and M. Greenwood-Nimmo, “Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework,” in *Festschrift in Honor of Peter Schmidt*, R. C. Sickles and W. C. Horrace, Eds. New York, NY, USA: Springer, 2014, pp. 281–314, doi: 10.1007/978-1-

4899-8008-3_9.

2. R. A. Amano and S. van Norden, "Oil prices and the rise and fall of the US real exchange rate," *J. Int. Money Finance*, vol. 17, no. 2, pp. 299–316, 1998, doi: 10.1016/S0261-5606(98)00004-7.
3. S.-S. Chen and H.-C. Chen, "Oil prices and real exchange rates," *Energy Econ.*, vol. 29, no. 3, pp. 390–404, 2007, doi: 10.1016/j.eneco.2006.08.003.
4. A. Bénassy-Quéré, V. Mignon, and A. Penot, "China and the relationship between the oil price and the dollar," *Energy Policy*, vol. 35, no. 11, pp. 5795–5805, 2007, doi: 10.1016/j.enpol.2007.05.035.
5. R. A. Lizardo and A. V. Mollick, "Oil price fluctuations and U.S. dollar exchange rates," *Energy Econ.*, vol. 32, no. 2, pp. 399–408, 2010, doi: 10.1016/j.eneco.2009.10.005.
6. S. A. Basher, A. A. Haug, and P. Sadorsky, "Oil prices, exchange rates and emerging stock markets," *Energy Econ.*, vol. 34, no. 1, pp. 227–240, 2012, doi: 10.1016/j.eneco.2011.10.005.
7. J. C. Reboredo, "Modelling oil price and exchange rate co-movements," *J. Policy Model.*, vol. 34, no. 3, pp. 419–440, 2012, doi: 10.1016/j.jpolmod.2011.10.005.
8. M. I. Turhan, E. Hacıhasanoglu, and U. Soytas, "Oil prices and emerging market exchange rates," *Emerg. Markets Finance Trade*, vol. 49, suppl. 1, pp. 21–36, 2013, doi: 10.2753/REE1540-496X4901S102.
9. S. Ghosh, "Examining crude oil price–exchange rate nexus for India during the period of extreme oil price volatility," *Appl. Energy*, vol. 88, no. 5, pp. 1886–1889, 2011, doi: 10.1016/j.apenergy.2010.10.043.
10. A. K. Tiwari, A. B. Dar, and N. Bhanja, "Oil price and exchange rates: A wavelet based analysis for India," *Econ. Model.*, vol. 31, pp. 414–422, 2013, doi: 10.1016/j.econmod.2012.11.043.
11. A. Jain and S. Ghosh, "Dynamics of global oil prices, exchange rate and precious metal prices in India," *Resour. Policy*, vol. 38, no. 1, pp. 88–93, 2013, doi: 10.1016/j.resourpol.2012.10.001.
12. M. H. Pesaran, Y. Shin, and R. J. Smith, "Bounds testing approaches to the analysis of level relationships," *J. Appl. Econometrics*, vol. 16, no. 3, pp. 289–326, 2001, doi: 10.1002/jae.616.
13. D. A. Dickey and W. A. Fuller, "Distribution of the estimators for autoregressive time series with a unit root," *J. Amer. Stat. Assoc.*, vol. 74, no. 366, pp. 427–431, 1979, doi: 10.1080/01621459.1979.10482531.
14. T. S. Breusch, "Testing for autocorrelation in dynamic linear models," *Aust. Econ. Papers*, vol. 17, no. 31, pp. 334–355, 1978, doi: 10.1111/j.1467-8454.1978.tb00635.x.
15. L. G. Godfrey, "Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables," *Econometrica*, vol. 46, no. 6, pp. 1293–1301, 1978, doi: 10.2307/1913829.
16. T. S. Breusch and A. R. Pagan, "A simple test for heteroscedasticity and random coefficient variation," *Econometrica*, vol. 47, no. 5, pp. 1287–1294, 1979, doi: 10.2307/1911963.
17. C. M. Jarque and A. K. Bera, "A test for normality of observations and regression residuals," *Int. Stat. Rev.*, vol. 55, no. 2, pp. 163–172, 1987, doi: 10.2307/1403192.
18. J. B. Ramsey, "Tests for specification errors in classical linear least-squares regression analysis," *J. Roy. Stat. Soc. B*, vol. 31, no. 2, pp. 350–371, 1969, doi: 10.1111/j.2517-6161.1969.tb00796.x.
19. R. L. Brown, J. Durbin, and J. M. Evans, "Techniques for testing the constancy of regression relationships over time," *J. Roy. Stat. Soc. B*, vol. 37, no. 2, pp. 149–192, 1975, doi: 10.1111/j.2517-6161.1975.tb01532.x.

20. Federal Reserve Bank of St. Louis, “Indian Rupees to U.S. Dollar Exchange Rate (EXINUS),” Federal Reserve Economic Data, 2021.
21. U.S. Energy Information Administration, “Crude Oil Prices: Brent–Europe (DCOILBRENTU),” distributed through FRED, 2021.
22. Board of Governors of the Federal Reserve System, “Trade Weighted U.S. Dollar Index: Broad, Goods and Services (DTWEXBGS) and Federal Funds Effective Rate (FEDFUNDS),” Federal Reserve Economic Data, 2021.
23. Organisation for Economic Co-operation and Development, “Immediate Rates: Call Money/Interbank Rate: Total for India (IRSTCI01INM156N),” Main Economic Indicators, distributed through FRED, 2021.