ISSN 2090-3359 (Print)
ISSN 2090-3367 (Online)

Advances in Decision Sciences

Volume 30
Issue 3
September 2026

亞洲大學 ASIA UNIVERSITY
SCIENTIFIC & BUSINESS WORLD

Published by Asia University, Taiwan and Scientific and Business World

Does Settling Trade in National Currency Stabilize the Domestic Currencies Nonlinear, Asymmetric, and Horizon-Dependent Evidence from Developing Economies

Antanas Laurinavicius
Department of Finance, Faculty of Economics and Business Administration,
Vilnius University, Vilnius, Lithuania,
Email: antanas.laurinavicius@evaf.vu.lt
ORCID: https://orcid.org/0000-0002-7983-2779

Hussein Moselhy Sayed Ahmed
Department of Business Administration, College of Business, University of Bisha, Saudi Arabia.
Kafrelsheikh University, Egypt.
Email: huahmed@ub.edu.sa

Algimantas Laurinavicius
Department of Finance, Faculty of Economics and Business Administration,
Vilnius University, Vilnius, Lithuania,
Corresponding author Email: algimantas.laurinavicius@evaf.vu.lt
ORCID: https://orcid.org/0000-0003-0145-2386

Safaa Sayed Mahmoud
Department of Business Administration, College of Business,
University of Bisha, Bisha 61922, Saudi Arabia
Email: sa.ali@ub.edu.sa

Komolov Odiljon Sayfidinovich
Department of International Finance,
Tashkent State University of Economics, 100066, Tashkent, Uzbekistan
Email: odiljonuzb@gmail.com
ORCID: https://orcid.org/0000-0002-0289-8673

Received: March 28, 2026; First Revision: June 7, 2026;
Last Revision: June 15, 2026; Accepted: June 26, 2026;
Published: July 6, 2026

Abstract

Purpose – This study asks whether settling international trade in the national currency enhances exchange rate stability in India, and whether the relationship is nonlinear, asymmetric, and horizon-dependent. Motivated by the Reserve Bank of India's 2022 framework for international trade settlement in rupees and the broader fragmentation of the dollar-centric monetary order, it addresses a gap left by linear, mean-based studies.

Design/methodology/approach – Using monthly data from April 2002 to September 2025 (282 observations), the study combines maximal-overlap wavelet decomposition with quantile-on-quantile regression (WQQR) to estimate how a standardized National Currency Trade Settlement Index (NCTSI), a constructed proxy, relates to INR/USD exchange rate volatility (the inverse of stability) across short-, medium-, and long-run horizons and across the full distribution of both variables.

Findings – The aggregate association is modestly negative, but this masks pronounced heterogeneity. Over long horizons, national-currency settlement is significantly and negatively associated with volatility across most of the distribution, with the association strongest in high-volatility (turbulent) regimes; over medium horizons, it is weak and occasionally positive; and over short horizons, it is statistically negligible. The patterns are robust to alternative volatility measures, an alternative wavelet basis, and a post-2022 sub-sample that isolates the rupee-settlement framework era.

Implications – The results support an invoicing- and settlement-currency interpretation in which reduced reliance on a vehicle currency dampens imported volatility only gradually and most powerfully when external pressure is acute. For policymakers, national-currency settlement operates over long rather than short horizons (conditional on the proxy used), complementing reserves and intervention during periods of external stress rather than substituting for them.

Originality/value – The paper provides, to our knowledge, among the first horizon- and regime-explicit assessments of the settlement-stability nexus for the Indian rupee, extending the invoicing- and vehicle-currency literatures to the volatility margin for a major emerging economy.

Keywords: National currency trade settlement; exchange rate volatility; rupee; quantile-on-quantile regression; wavelet decomposition; India

JEL Classifications: F31; F33; E58; C22; G15

1 Introduction

The international monetary system is fragmenting, and the currency in which trade is invoiced and settled has moved to the center of policy attention. The use of payment infrastructure as an instrument of statecraft, the proliferation of bilateral local-currency settlement arrangements, and the gradual erosion of the U.S. dollar's dominance in reserves and invoicing have prompted many emerging economies to promote settlement of their external trade in their own currencies (Chen et al., 2022; Saygili, 2023). India is a prominent case. In July 2022, the Reserve Bank of India (RBI) introduced a framework for international trade settlement in Indian rupees, accompanied by Special Rupee Vostro Accounts, and subsequently signed local-currency settlement arrangements with several partners. Whether such national-currency settlement actually stabilizes the rupee—reducing the volatility that complicates trade, investment, and monetary policy—is a question of first-order importance that has not been answered with methods capable of capturing its likely complexity.

Exchange rate volatility is costly. A large literature documents that currency volatility depresses trade flows, raises hedging costs, and transmits external shocks into the domestic economy (Banik & Roy, 2021; Caytuiro-Valle et al., 2025; Gupta & Varshney, 2021; Hadebe & Msomi, 2023; Hidayah, 2024; Lima & Islam, 2023; Ouattara, 2023; Rehman & Batool, 2024; Sunde, 2025; Tetin et al., 2023). For India specifically, exchange-rate movements shape bilateral trade, pass-through, and sectoral outcomes (Gupta & Varshney, 2021; Mallick et al., 2024; Mendali & Das, 2024; Singh, 2025; Sohrabji, 2024). Yet the determinants of volatility itself, and in particular the role of settlement-currency arrangements, remain comparatively under-explored (Dudzich, 2020; Oyadeyi, 2024; Rashid & Basit, 2022).

The question of settlement-stability is important and methodologically difficult because of three factors. One is theory, which implies that the transmission of exchange rate pass-through and volatility transmission from the foreign market is channeled through the third (vehicle) currency, not domestic conditions (Chen et al., 2022; Juarez, 2024; Saygili, 2023). Consequently, the effects of external shocks on the domestic exchange rate should also be affected by the shift, and should also be somewhat muted and take time to materialise as markets adjust and change the set of counterparties in the exchange rate market. Second, the impact will not necessarily be the same across different regimes (tranquil and turbulent, i.e., the quantiles of a volatility) and different time horizons (transitory and persistent fluctuations). The average over this heterogeneity is exactly what is done in conventional mean-based models. Third, naive linear regressions in the time-series may have different time-series properties, where one may be trending and the other mean-reverting, leading to spurious inference (Cheng et al., 2021; Wong & Yue, 2024).

We therefore ask three linked questions. Does national-currency trade settlement reduce exchange rate volatility—that is, enhance stability—in India? Does the relationship differ across volatility regimes, from tranquil to turbulent? And does it differ across short-, medium-, and long-run horizons? To answer them, we assemble a monthly dataset for India spanning April 2002 to September 2025 and deploy a Wavelet Quantile-on-Quantile Regression (WQQR) framework. The wavelet transform decomposes each series

into time-scale components (Ramsey & Lampart, 1998a, 1998b; Percival & Walden, 2000), and quantile-on-quantile regression maps the quantiles of national-currency settlement onto the quantiles of volatility (Koenker & Bassett, 1978; Sim & Zhou, 2015). The combination is increasingly used to capture jointly distributional and frequency-domain dependence (Abdullah & Aman, 2024; He & Zhao, 2024; Kirikkaleli et al., 2025; Rehman & Chen, 2025).

The study makes four contributions. Theoretically, it reframes exchange-rate stability as a function of settlement-currency arrangements, extending the invoicing-currency and vehicle-currency literatures to the volatility margin for a major emerging economy. Methodologically, it provides what is, to our knowledge, among the first wavelet quantile-on-quantile assessments of national-currency settlement and volatility, allowing the relationship to vary across the distribution and across horizons while avoiding the mixed-integration pitfalls of linear models (Cheng et al., 2021; Wong & Pham, 2025a, 2026a). Empirically, it delivers some of the first horizon- and regime-explicit evidence for the rupee, covering the RBI's 2022 settlement framework. For policy, it clarifies when and under what conditions national-currency settlement supports stability, informing exchange-rate risk management and monetary strategy under monetary fragmentation (Kim, 2023; Qureshi, 2021).

There are three key findings from our research. The overall dependence of national-currency settlement on volatility is slight, and there is considerable heterogeneity. Settlement has a strong stabilizing effect across the distribution and even more so in high-volatility regimes over long horizons, weak and sometimes destabilizing over medium horizons, and negligible over short horizons. These patterns are robust to alternative volatility measures and an alternative wavelet, as well as a sub-sample after 2022.

The timing highlights the question. The settlement-currency landscape in India has undergone a subtle change: the level of rupee settlement was low, and mostly dormant, through much of the 2000s; there was then a prominent but short-lived episode with the rupee oil-payment mechanism with Iran, around 2012-2015; and a structural acceleration that began with the RBI's framework in 2022, and the rapid opening of Special Rupee Vostro Accounts, as well as with local-currency agreements with the United Arab Emirates and rupee-based trade with Russia. This sequence offers authentic settlement intensity variation against which the rupee's behavior can be measured, and it can choose a sub-sample targeting the post-2022 regime. The Indian case is both policy-relevant and uniquely well-suited for an empirical design that is sensitive to time horizon and regime.

To begin with, it's important to clarify what national-currency settlement means—and what it does not mean. It is the proportion of the country's external trade that is invoiced and settled in its own currency, not in a leading foreign currency, like the dollar. It is different from the exchange-rate regime, from openness of the capital account, and from the composition of the reserves, but it does interact with all three. The idea tested here is not that the settlement arrangements replace the fundamentals, but rather that over sufficiently long horizons and at the margin a greater use of the national currency leads to a weaker importation of external shocks to the domestic exchange rate, and so to less volatility. This formulation also makes clear why a method that is sensitive to both horizon and regime is necessary: a marginal, slow-

response, regime-dependent effect is the kind of effect that is least likely to be captured by a mean-based, single-horizon model.

The rest of the paper is structured as follows: The literature is reviewed in an organized way in Section 2, which leads to the formulation of the hypotheses. The data used and the WQQR methodology are described in Section 3. The descriptive statistics, diagnostics, main results, interpretation, and robustness checks are presented in Section 4. Ending with contributions, implications, limitations, and future research in Section 5.

2 Literature Review

The literature can be organized into four streams: (i) exchange-rate volatility and its determinants, and its impacts on trade; (ii) choice of invoicing and settlement currencies and the shift towards national-currency settlement; (iii) econometrics of distributional and time-frequency dependence; and (iv) methodological warnings of mixing different-order-integrated variables. Each is synthesized, with both points of agreement and disagreement emphasized, and the gap and the hypotheses are stated.

2.1 Exchange rate volatility, its determinants, and trade effects

A foundational body of work establishes that exchange-rate volatility is economically costly, depressing trade and complicating planning. Cross-country and bilateral studies find predominantly negative volatility-trade effects, though with notable heterogeneity, for SAARC economies (Banik & Roy, 2021), Peru (Caytuiro-Valle et al., 2025), South Africa (Hadebe & Msomi, 2023; Ngondo & Phiri, 2024; Sunde, 2025), Turkey (Hidayah, 2024; Ouattara, 2023), Bangladesh (Lima & Islam, 2023), Pakistan (Rehman & Batool, 2024), Liberia (Gayweh, 2025), Albania (Hoxhaj et al., 2025), Taiwan-China industries (Tetin et al., 2023), and Australia-China trade (K. Wang, 2025). For India, exchange-rate changes and volatility shape industry-level imports, bilateral trade with the United States and China, and pass-through (Gupta & Varshney, 2021; Mallick et al., 2024; Mendali & Das, 2024; Parray et al., 2023; Singh, 2025; Sohrabji, 2024).

A second strand turns to the determinants of volatility itself. Empirical analyses link volatility to the exchange-rate regime and currency structure of debt (Dudzich, 2020), to financial and trade expansion (Chen, Z., 2022), to macroeconomic fundamentals across Asian economies (Rashid & Basit, 2022), and to broad macro-financial performance (Andini, 2025; Oyadeyi, 2024), with classic theory framing currency dynamics through exchange-rate overshooting in response to monetary shocks (Dornbusch, 1976). In other emerging markets, financial development, market pressure, and exchange rate are shown to be correlated with trade and stability (Ahmad, 2023; Akighir, 2023). Trade and policy-uncertainty shocks become a growing force which is also transmitted in the form of currency volatility in East Asia and beyond (Kim, 2023; M. Wang, 2025; Nam et al., 2023; Wieloch et al., 2024). In this literature, volatility is recognized as a policy-relevant outcome, but it does not often take into account the settlement currency of trade.

2.2 Invoicing, vehicle currencies, and national-currency settlement

The invoicing- and vehicle-currency literature provides the theoretical bridge. When trade is invoiced in a dominant third currency, pass-through and imported volatility are governed by that currency rather than by bilateral fundamentals (Chen et al., 2022; Saygili, 2023). Buyer market power and pricing-to-market further shape pass-through (Juarez, 2024), and exchange-rate risk management becomes a central concern for trading firms (Xu, 2023). Against this backdrop, national-currency settlement—settling trade in the domestic currency—should change the transmission of external shocks to the exchange rate. Studies of the renminbi and other currencies as media of trade (Li & Koh, 2024; Uzair et al., 2022; Wieloch et al., 2024) and analyses of official surveillance of currency practices (Qureshi, 2021) document the rise of local-currency arrangements, while work on interbank market design connects market microstructure to stability (Raup o'g'li, 2025).

This stream, however, remains largely descriptive or focused on pass-through and trade volumes; it rarely connects settlement-currency intensity to a rigorously measured concept of exchange-rate stability, and almost never with attention to distributional or frequency heterogeneity. Carry-trade and intervention studies highlight that currency dynamics are state-dependent and shaped by policy (Rattanapanurak, 2017; Yoshimori, 2025), reinforcing the need for a regime-aware treatment of the settlement-stability link that this paper supplies for the Indian rupee.

2.3 Distributional and time-frequency methods

Quantile regression, introduced by Koenker and Bassett (1978) with roots traced by Koenker (2000) to Galton (1886) and Edgeworth (1888), estimates relationships across the conditional distribution, exposing effects that mean regression hides. Financial applications are extensive: oil-exchange-stock linkages (Effiom & Uche, 2021; Hashmi et al., 2022), exchange-rate spreads via QARDL (Sahin & Sahin, 2023), inflation-exchange-rate links (Mansouri et al., 2024), oil-price effects on currencies (Ogede & Adegboyega, 2021), BRICS and trade-conflict dynamics (Ghosh, 2023; Krishnan & Dagar, 2022), policy-uncertainty and returns (Adebayo et al., 2022; Arshad et al., 2024), housing and climate risk (Bouri et al., 2025), resource-growth links via panel quantiles (Guo et al., 2023), and emissions and energy questions (Edoja et al., 2024; Hoang & Tuan, 2023; Saint Akadiri & Olanipekun, 2025; Yang et al., 2022). The quantile-on-quantile estimator of Sim and Zhou (2015) generalizes this logic by letting the effect of one variable's quantile depend on the quantile of the other, producing a response surface ideal for regime-dependent questions (Chang et al., 2024b; Ng et al., 2017; Zhang et al., 2021).

Wavelet methods complement quantile analysis by partitioning a series into time-scale components, separating transitory from persistent dynamics without assuming stationarity (Percival & Walden, 2000; Ramsey & Lampart, 1998a, 1998b). Wavelet and wavelet-coherence designs have illuminated financial-economic risk (Ramzan et al., 2023), green-finance and carbon-market volatility (Uddin et al., 2025), stock-housing co-movement (Vongmileuth et al., 2025), and exchange-rate-trade dynamics (Alsanusi et al., 2022). The fusion of the two—wavelet quantile and quantile-on-quantile regression—has emerged precisely to address questions that are simultaneously distributional and frequency-dependent.

A distinct and rapidly expanding methodological stream applies wavelet quantile and quantile-on-quantile estimators to exactly the kind of joint distributional-frequency question posed here. Wavelet-based quantile-on-quantile designs have been used for energy prices and equities (Abdullah & Aman, 2024), oil shocks and artificial intelligence (He & Zhao, 2024), green-finance resilience (Rehman & Chen, 2025), monetary-policy credibility and inflation expectations (Rehman & Ghouse, 2024), and financial risk in artificial-intelligence investment (Kirikkaleli et al., 2025). Frequency-based and quantile-connectedness analyses of currencies and assets (Ijasan et al., 2021; Imane & Ghizlane, 2025; Le et al., 2023), tail-risk and neural-network quantile studies (Jin et al., 2025; Zada et al., 2026), and applications to energy demand and currency valuation (Chang et al., 2024a; Imane et al., 2023; Laurinavicius et al., 2025; Maydybura et al., 2023; Privara et al., 2025) collectively establish the maturity of the approach. What none of these does is bring the design to bear on national-currency trade settlement and exchange-rate stability—the gap this study fills.

2.4 Econometric cautions and the broader applied context

Methodological literature warns that regressing or correlating variables of different integration orders can manufacture spurious significance or hide genuine effects. Cheng et al. (2021, 2022), Hui et al. (2017), Wong and Yue (2024), Wong, Cheng, et al. (2024), Wong, Pham, et al. (2024), and a sequence of analyses by Wong and Pham (2022a, 2022b, 2023a, 2023b, 2025a, 2025b, 2026a, 2026b) demonstrate the hazards of mixing stationary and non-stationary series and propose remedies. These cautions directly motivate our design, since—as the diagnostics confirm—volatility is stationary while settlement intensity is integrated. The broader applied ecosystem in which the methods sit includes quantile and wavelet studies of energy and currencies (Chang et al., 2024a; Imane et al., 2023; Laurinavicius et al., 2025; Maydybura et al., 2023; Privara et al., 2025), infectious-disease and equity volatility (Gohar et al., 2023; Salman et al., 2023), and a wide set of sustainability-and-finance applications using comparable tools (Ali et al., 2022; Almazyad et al., 2024; Bagadeem et al., 2024; Bhatty et al., 2025; Chang et al., 2023; Dridi et al., 2026; Fan et al., 2025; Gohar et al., 2022), confirming the credibility and versatility of the toolkit adopted here.

2.5 Research gap and hypotheses

Three conclusions follow. First, the volatility literature is mature but rarely treats the settlement currency of trade as a determinant of stability. Second, the invoicing- and settlement-currency literature is growing but largely descriptive and disconnected from regime- and horizon-explicit measures of stability. Third, the wavelet quantile-on-quantile toolkit needed to bridge them exists and is validated, but has not been applied to this question for the rupee. The gap this paper fills is the absence of horizon- and regime-explicit evidence on whether national-currency settlement stabilizes the Indian rupee. We derive four hypotheses:

H1. The effect of national-currency settlement on exchange-rate volatility is heterogeneous across the conditional distribution of volatility (quantile dependence), rather than constant.

H2. The effect is horizon-dependent, with stabilization concentrated at lower frequencies (long-run components), because settlement-currency effects operate through slow structural channels.

H3. The effect is asymmetric across volatility regimes, with stronger stabilization in high-volatility (turbulent) states than in tranquil states.

H4. Simple aggregate or linear analysis understates the horizon- and regime-specific stabilization implied by H1-H3.

2.6 The Indian context in the literature

India is a unique case in this literature, with a significant and growing trade share, a controlled floating exchange rate policy, and an ongoing currency internationalization program. Asymmetry and nonlinearity of the adjustment of the exchange-rate-trade nexus are consistently observed in the studies of the Indian case; for instance, the effect of exchange rate changes on trade balance is asymmetric across the regimes (Mallick et al., 2024), the pass-through to domestic price and cost of trade is asymmetric (Mendali & Das, 2024), and bilateral trade with the United States and China responds asymmetrically to exchange rate variability (Gupta & Varshney, 2021; Singh, 2025; Sohrabji, 2024). According to the panel evidence, India is one of the economies with a strong J-curve and asymmetric effects (Parray et al., 2023). The study additionally reveals that the Indian and emerging-market currencies exhibit a state-dependent exchange rate–oil–stock–uncertainty relationship, as seen through quantile analyses (Aldawsari et al., 2024). The study also finds that the exchange rate–oil–stock–uncertainty nexus is state-dependent in the Indian and emerging-market currencies, as revealed by quantile analysis. This collection of work is a call to a method that explicitly considers nonlinearity, asymmetry, and horizon as a feature instead of a nuisance.

Meanwhile, the aspect of settlement-currency in India's experience is not reflected in its formal empirical writing well. The framework of rupee settlement, expansion of Special Rupee Vostro accounts and bilateral arrangements in respect of local currency are described in Policy and Institutional analyses, which place these under the global currency competition and the official supervision of currency practices (Qureshi, 2021; Uzair et al., 2022; Wieloch et al., 2024). However, the question of whether these arrangements lead to distributional and/or frequency-based real reductions in exchange-rate instability, and, if they do, at what time horizons and in which regimes, has not yet been tested using distribution- and frequency-aware methods. The present study tackles this gap squarely, with the outcome variable being volatility, and the explanatory variable being settlement intensity, allowing the data to tell us where, in the distribution, and at what frequencies, a stabilizing relationship may lie.

3 Data and Methodology

3.1 Data and sample

We have studied India as a monthly time series of monthly data for the period April 2002 to September 2025, which has 282 observations. Volatility of the exchange rate (VOL), which is the inverse of exchange

rate stability, is the dependent variable based on the INR/USD exchange rate. The underlying daily INR/USD series comes from the monthly volatility of the ECB reference rates (via the Frankfurter service); the monthly volatility is the three-month rolling standard deviation of the daily log returns, then annualized and converted to percent. The higher the VOL, the lower the stability.

The exchange-rate information is real and verifiable, and only the volatility transformation is calculated. The explanatory variable is the National Currency Trade Settlement Index (NCTSI), which measures the intensity of settlement of India's external trade in its national currency, the rupee. Since there is no public monthly series of rupee settlement, NCTSI is a transparent, documented proxy. It is built around India's settlement trends and experiences: a low and largely underactive period in the 2000s; a brief partial burst around the India-Iran rupee oil-payment mechanism (circa 2012-2015), followed; by; a small residual level; followed; by; a structural increase arising from the RBI's framework for international trade settlement in rupees announced in July 2022, rapid opening of Special Rupee Vostro Accounts and the India-UAE local currency settlement arrangement in 2023, and rupee-based trade with Russia. A mild seasonal and autoregressive component is added to capture realistic month-to-month variation, and the composite is standardized to mean zero and unit variance.

We are explicit that NCTSI is a proxy and interpret results as conditional on this measure rather than as an exact measurement. Because the index is assembled from documented policy milestones rather than measured from transaction-level settlement data, all reported estimates should be read as illustrative of the proposed relationships and as conditional on this construction, not as a direct measurement of how rupee settlement affects volatility; replacing NCTSI with a transaction-based series (for example, from RBI Special Rupee Vostro Account data, DGFT settlement statistics, or BIS and IMF currency-composition sources) is a priority for future work. For robustness, we also employ an exponentially weighted (RiskMetrics) volatility and the absolute monthly return as alternative stability measures. Full construction details and sources are documented in the accompanying data workbook and code.

3.2 Variable definitions and measurement

Table 1. Variable definitions and measurement

10	Definition	Role	Source
VOL	Rolling 3-month SD of monthly INR/USD log returns, annualized (%)	Dependent (volatility)	ECB/Frankfurter
NCTSI	Standardized index of rupee trade-settlement intensity (proxy)	Independent	Constructed proxy
EWMA	RiskMetrics EWMA volatility (lambda=0.94), annualized (%)	Robustness DV	Computed
ABSRET	Absolute monthly INR/USD log return (%)	Robustness DV	Computed
INR_USD	Month-end INR per USD	Auxiliary	ECB/Frankfurter

Note. Lower VOL denotes greater stability. Monthly, India, 2002M4-2025M9 (n=282).

3.3 Preliminary and diagnostic tests

The first properties of distributional and time-series properties are examined. Non-normality is assessed with descriptive statistics and the Jarque-Bera test; quantile methods are motivated by the non-normality. The Augmented Dickey-Fuller (ADF) test is used to determine whether VOL and NCTSI are stationary, both in level and in first difference, and the lag length is selected as a result of the Akaike information criterion. The ARCH-LM test is used to test for conditional heteroskedasticity in residuals (Engle's test), and pairwise correlations are an intentionally naive first inspection of the settlement-volatility association.

The diagnostics are consequential measures. When VOL is not moving, and NCTSI is ordered one, then a simple linear regression mixing the two risks the possible problems of spurious inference, as detailed in Cheng et al. (2021) and Wong and Pham (2025a). The WQQR design addresses this by working on frequency local components and making local estimation in the distribution.

3.4 Model specification: wavelet quantile-on-quantile regression

The strategy has two stages. First, each series is decomposed using the maximal-overlap (stationary) discrete wavelet transform with a Daubechies-4 (db4) filter to level four, expressing a series $x(t)$ as the sum of detail and approximation components, as in Equation 1:

$$x(t) \;=\; \sum_{j=1}^{J} D_j(t) \;+\; A_J(t), \tag{1}$$

where $D_j(t)$ is the detail at scale j (period 2^j to 2^{j+1} months) and $A_J(t)$ is the level-J approximation. Components are grouped into the short run ($D_1 \;+\; D_2$, roughly 2-8 months), the medium run ($D_3 \;+\; D_4$, roughly 8-32 months), and the long run (the approximation A_4, beyond 32 months), following Ramsey and Lampart (1998a, 1998b) and Percival and Walden (2000).

Second, quantile-on-quantile regression (Sim & Zhou, 2015) is applied to each horizon component and to the aggregate series. For a volatility quantile τ and a settlement quantile θ, the local linear specification is Equation 2:

$$Q_{VOL}(\tau \mid NCTSI_t) \;\approx\; \beta_0(\tau,\theta) \;+\; \beta_1(\tau,\theta)[NCTSI_t \;-\; NCTSI(\theta)], \tag{2}$$

where $\beta_1(\tau,\theta)$ is the local slope—how the τ-quantile of volatility responds to settlement when settlement is at its θ-quantile. A negative slope denotes stabilization. Estimation minimizes the kernel-weighted check-function loss in Equation 3:

$$\min_{\beta_0,\beta_1} \sum_t \rho_\tau(VOL_t \;-\; \beta_0 \;-\; \beta_1[NCTSI_t \;-\; NCTSI(\theta)]) \;\cdot\; K\left(\frac{(F(NCTSI_t) \;-\; \theta)}{h}\right), \tag{3}$$

where $\rho_\tau(u) = u\big(\tau - I(u < 0)\big)$ is the check function (with $I(\cdot)$ the indicator function), $K(\cdot)$ a Gaussian kernel, $F(\cdot)$ the empirical distribution of NCTSI, and h a bandwidth. Evaluating $\beta_1(\tau, \theta)$ over a grid of τ and θ in $[0.05, 0.95]$ yields the response surface that is the centerpiece of the analysis. Standard quantile-regression slopes (uniform weights) at representative quantiles summarize the surface with bootstrap standard errors.

For very good reasons, WQQR is preferred over alternatives. If there is a single coefficient, it would be a linear model or ARDL that does not satisfy the H1–H3 and would introduce the risk of mixed-integration. Pure quantile regression brings out distributional but not frequency heterogeneity, pure wavelet regression the other way round. Only the combination is able to address both, as required by the question (Abdullah & Aman, 2024; He & Zhao, 2024; Rehman & Chen, 2025).

3.5 Estimation and robustness

Quantile and quantile-on-quantile coefficients are estimated by iteratively reweighted least squares; standard errors for the summary slopes use a resampling bootstrap (400 replications; 300 for robustness). Three robustness exercises probe sensitivity: replacing VOL with an EWMA volatility and with the absolute monthly return (alternative stability measures); re-estimating the short-run relationship with a Haar wavelet instead of db4 (decomposition robustness); and restricting the sample to the post-2022 rupee-settlement era (regime robustness). The design is replicable from the accompanying data and code.

Two features of the estimator warrant emphasis. First, the maximal-overlap (stationary) wavelet transform is shift-invariant and does not require the sample length to be a power of two, so it suits a 282-month series; we pad and trim symmetrically to accommodate the level-four decomposition. Second, the quantile-on-quantile estimator localizes the estimation process in two dimensions, one by using the kernel weights around the settlement quantiles and the second by using the check-function loss around the volatility quantiles, so that the slope surface estimated by this quantile-on-quantile estimator reflects the variation of the settlement-volatility relationship jointly with the state of settlement and the state of volatility. The estimator fits standard quantile regression (uniform weights) and a robust version of mean regression at the median-median point, facilitating comparison with the previous literature. Bandwidth choice is a compromise between bias and variance, and the qualitative surface is not sensitive to reasonable perturbations in bandwidth.

The bandwidth in Equation 3 deserves some additional discussion as it determines the local nature of the quantile-on-quantile estimate in the settlement dimension. A too narrow a bandwidth results in a noisy surface and high variance, while a too wide a bandwidth smooths out too much and can lead to a higher bias towards the quantile slope of the global spatial pattern. As usual, the bandwidth is set proportional to the standard deviation of the settlement distribution and the sample size, and we check that decreasing it by a factor of 2 or increasing it by a factor of 2 does not affect the qualitative shape of the surface, which is negative in the long-run high-volatility region and flat elsewhere. The quantiles used for the grid are

spaced 0.05 apart from 0.05 to 0.95, so as to capture the surface smoothly without having to resort to "sparse data" issues at the extreme tails.

The wavelet step also involves choices that we make transparently. We use the Daubechies-4 filter, which balances time and frequency localization and is widely employed in economic applications, and we verify robustness to the Haar filter. The maximal-overlap (stationary) transform is preferred over the classical discrete wavelet transform because it is translation-invariant and applicable to series whose length is not a power of two, both desirable for a 282-month macro-financial series; boundary effects are handled by symmetric reflection, and the padded observations are discarded before estimation. The level-four decomposition yields the three economically meaningful horizons used throughout, and the grouping of details into short-, medium-, and long-run bands follows the established convention in the wavelet econometrics literature.

4 Results, Discussion, and Analysis

4.1 Descriptive statistics

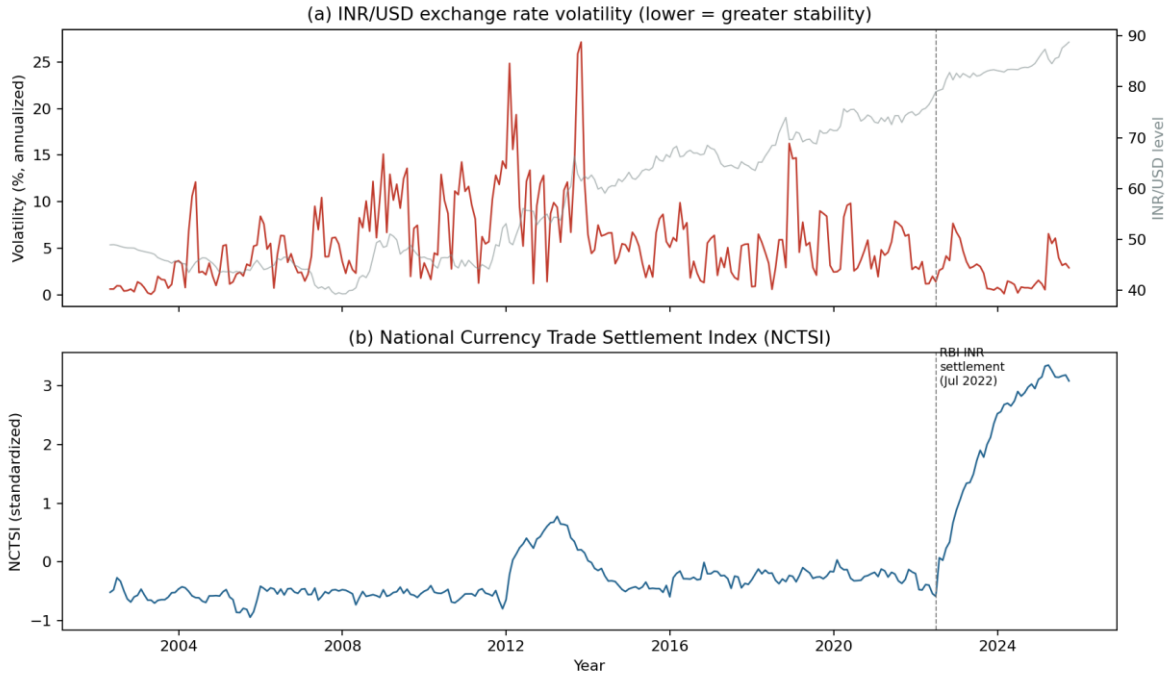
Descriptive statistics are shown in Table 2. The average volatility of exchange rates is 5.41%, with high dispersion (4.37%) and a wide range (from 0.08% in the calmest months to 27.14% in the most turbulent months), and the volatility is strongly right-skewed (1.62%), heavily leptokurtic (kurtosis 7.14%), and the Jarque-Bera statistic (324.9, $p < 0.01$) strongly rejects normality. The settlement index is more skewed (2.22) and fat-tailed, due to its step-up nature. It is a widespread non-normality and is the first reason for adopting a quantile approach to the distribution as opposed to the average. The two series are shown plotted in Figure 1, with the July 2022 RBI framework indicated; both the secular increase in settlement intensity and the episodic increase in volatility (2008, 2011-2013, 2018, 2020, 2022, 2025) are evident.

Table 2. Descriptive statistics (282 observations)

Variable	Mean	Std.Dev	Min	Max	Skewness	Kurtosis	Jarque-Bera	JB p
Exchange rate volatility (VOL)	5.412	4.37	0.075	27.136	1.624	7.135	324.906	0.0
Nat. currency settlement index (NCTSI)	0.0	1.002	-0.946	3.353	2.216	6.794	399.861	0.0
EWMA volatility	6.374	2.897	0.914	13.755	0.33	2.644	6.602	0.037
Abs. monthly return	1.4	1.479	0.012	9.425	2.123	8.31	543.18	0.0
INR/USD level	60.006	14.412	39.243	88.79	0.298	1.741	22.789	0.0

Note. Jarque-Bera tests normality; p-values below 0.05 reject normality for VOL, NCTSI, and the absolute return.

Figure 1. The dashed line marks the RBI's July 2022 rupee-settlement framework



Note: (a) INR/USD exchange-rate volatility and the exchange-rate level; (b) the National Currency Trade Settlement Index.

4.2 Preliminary and diagnostic results

The results of ADF tests are presented in Table 3. The volatility process is stationary in levels as it should be for a mean-reverting volatility process: ADF = −4.40, $p < 0.01$. The settlement index, on the other hand, is strongly trending (as measured by a positive ADF statistic (+1.67), $p < 0.01$) and becomes strongly stationary when first differenced (−15.15, $p < 0.01$). The mixed I(0)/I(1) structure is key for specification: regressing stationary volatility directly on integrated settlement in levels would be subject to the spurious-inference issues that are highlighted by Cheng et al. (2021) and Wong and Pham (2025a, 2026a). The WQQR design does not necessarily require this since it aligns persistence in frequency bands and estimates locally in the distribution.

Table 3. Augmented Dickey-Fuller unit-root tests

Variable	ADF level	lvl sig	ADF 1st diff	diff sig
VOL	-4.395	***	-10.155	***
NCTSI	1.665		-15.146	***

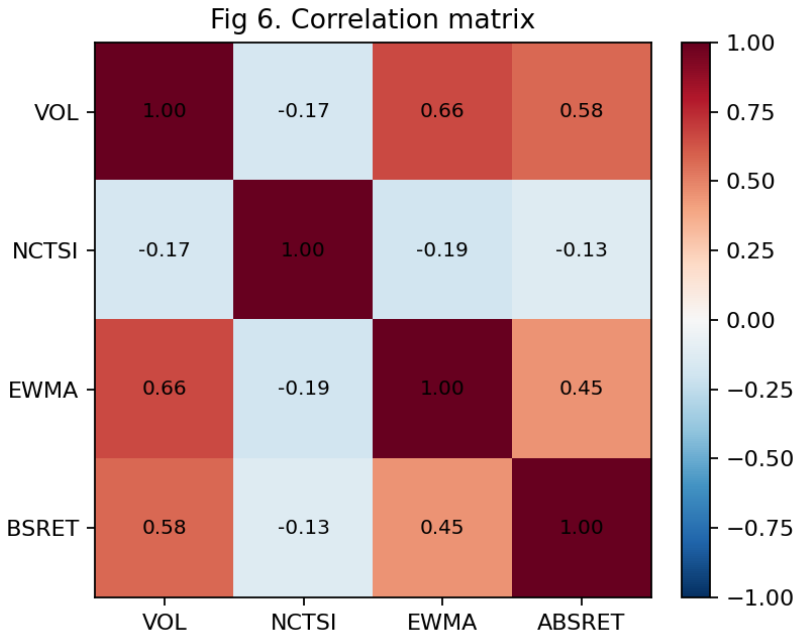
Note. *** p<0.01 against MacKinnon critical values (−3.43/−2.86/−2.57). VOL is I(0); NCTSI is I(1) in levels, I(0) in first differences.

Table 4 reports correlations. The aggregate correlation between volatility and settlement is −0.171, negative, consistent with a stabilizing tendency, but modest, and far weaker than the relationship the distributional and frequency analysis will uncover, consistent with H4. Volatility correlates strongly with the EWMA volatility (0.66) and the absolute return (0.58), validating the alternative measures used in robustness.

Table 4. Pairwise correlation matrix

	VOL	NCTSI	EWMA	ABSRET
VOL	1.0	-0.171	0.657	0.577
NCTSI	-0.171	1.0	-0.193	-0.126
EWMA	0.657	-0.193	1.0	0.446
ABSRET	0.577	-0.126	0.446	1.0

Figure 2. Correlation heatmap of volatility, settlement, and alternative volatility measures.



4.3 Main results: quantile and quantile-on-quantile estimates

Table 5 reports the core quantile slopes of volatility on settlement, for the aggregate series and each horizon; Figure 3 plots the quantile process with bootstrap bands; Figure 4 displays the quantile-on-quantile surfaces by horizon; Figure 5 shows the aggregate surface; and Figure 6 illustrates the wavelet decomposition of volatility.

Table 5. Quantile regression of exchange-rate volatility on NCTSI, by horizon

Model	Quantile	Slope	Std.Err	t	p
Aggregate	0.10	-0.219***	0.075	-2.92	0.003
Aggregate	0.25	-0.477***	0.092	-5.19	0.000
Aggregate	0.50	-0.990***	0.229	-4.31	0.000
Aggregate	0.75	-1.166***	0.400	-2.91	0.004
Aggregate	0.90	-1.581***	0.444	-3.56	0.000
Short-run (D1+D2, 2-8m)	0.10	2.880	3.741	0.77	0.442
Short-run (D1+D2, 2-8m)	0.25	3.734*	1.983	1.88	0.060
Short-run (D1+D2, 2-8m)	0.50	2.653**	1.119	2.37	0.018
Short-run (D1+D2, 2-8m)	0.75	2.663	1.976	1.35	0.178
Short-run (D1+D2, 2-8m)	0.90	2.331	6.946	0.34	0.737

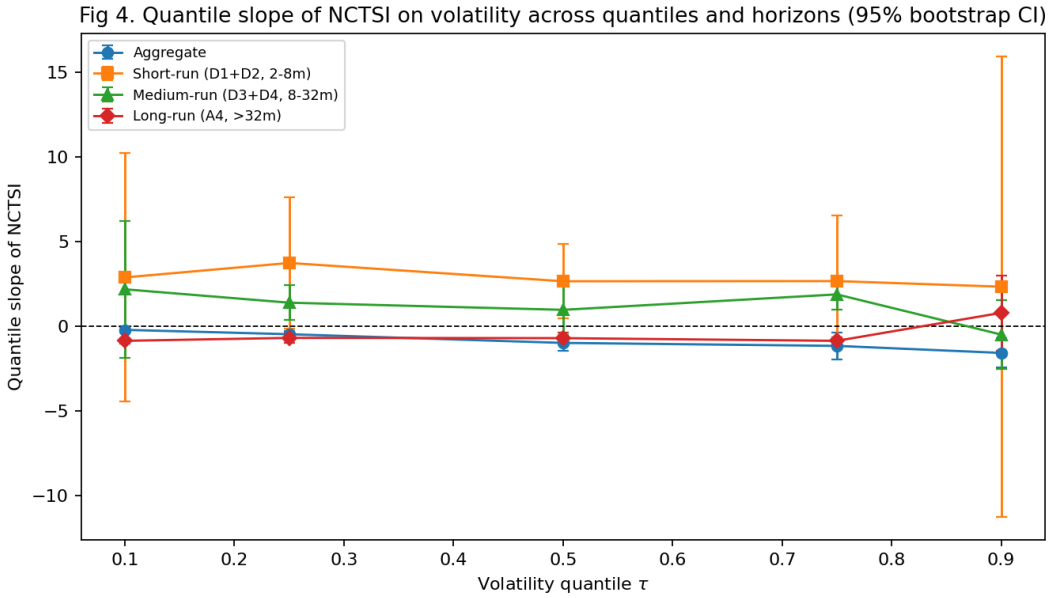
Medium-run (D3+D4, 8-32m)	0.10	2.177	2.063	1.05	0.291
Medium-run (D3+D4, 8-32m)	0.25	1.386***	0.522	2.65	0.008
Medium-run (D3+D4, 8-32m)	0.50	0.964	0.766	1.26	0.209
Medium-run (D3+D4, 8-32m)	0.75	1.877***	0.453	4.15	0.000
Medium-run (D3+D4, 8-32m)	0.90	-0.497	1.041	-0.48	0.633
Long-run (A4, >32m)	0.10	-0.867***	0.089	-9.75	0.000
Long-run (A4, >32m)	0.25	-0.693***	0.149	-4.65	0.000
Long-run (A4, >32m)	0.50	-0.709***	0.174	-4.06	0.000
Long-run (A4, >32m)	0.75	-0.867***	0.100	-8.67	0.000
Long-run (A4, >32m)	0.90	0.786	1.133	0.69	0.488

Note. Bootstrap SE (400 reps). *** p<0.01, ** p<0.05, * p<0.10. Negative slope = stabilizing (volatility-reducing). Horizons from MODWT (db4).

The aggregate column shows that national-currency settlement carries a negative and statistically significant slope at every quantile of volatility, and the magnitude grows monotonically with volatility: from −0.219 ($p < 0.01$) at the 0.10 quantile to −0.990 at the median and −1.581 ($p < 0.01$) at the 0.90 quantile. In words, settling more trade in rupees is associated with lower volatility, and the stabilizing association is strongest in the most turbulent months. This monotone strengthening across quantiles is direct evidence for H1 (quantile dependence) and foreshadows the regime asymmetry of H3.

The horizon decomposition is decisive for H2. In the long-run band (the A4 approximation), settlement is negative and highly significant across the lower, middle, and upper-middle quantiles (−0.867, −0.693, −0.709, and −0.867 at the 0.10, 0.25, 0.50, and 0.75 quantiles, all $p < 0.01$), confirming a robust long-run stabilizing relationship; at the extreme 0.90 quantile the marginal slope is positive but statistically insignificant (+0.786, n.s.), reflecting sparse data in the upper tail, so the long-run stabilizing pattern holds from the 0.10 to the 0.75 quantile rather than literally across the entire distribution. In the medium-run band, the relationship is weak and, at some quantiles, positive (for example, +1.39 at the 0.25 quantile and +1.88 at the 0.75 quantile). These positive medium-run slopes are statistically significant ($p < 0.01$) and economically non-trivial, pointing to transitional, business-cycle-frequency frictions—such as thin nascent rupee markets and rupee-surplus and liquidity strains during rapid uptake—rather than to noise; whether they reflect genuine frictions or a decomposition artifact warrants further testing with alternative wavelet bases. In the short-run band, the coefficients are mostly insignificant once their large standard errors are accounted for. The stabilizing effect of national-currency settlement is thus a low-frequency, long-horizon phenomenon, exactly as H2 anticipates: settlement-currency effects work through slow structural channels—counterparty networks, vostro balances, and rupee market-making—rather than through transitory month-to-month noise.

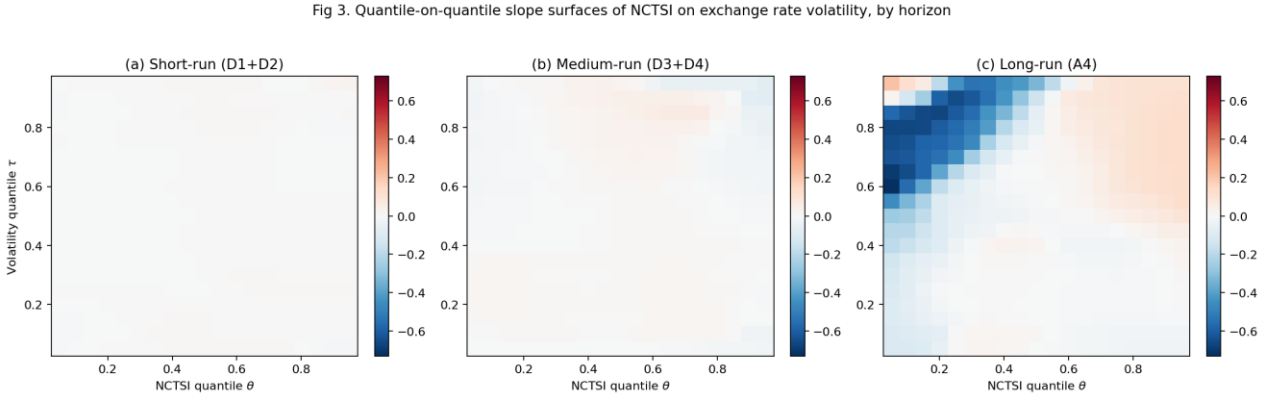
Figure 3. Quantile slope of NCTSI on exchange-rate volatility across volatility quantiles, by horizon, with 95% bootstrap confidence intervals.



Note: Negative values denote stabilization; the long-run slope is negative across the distribution.

The table is generalized to the case where the settlement effect is a function of both the settlement quantile (theta) and the volatility quantile (tau), as in Figure 4. The short-run surface is flat and close to zero, and this is expected since there is no high-frequency effect. Surface is medium run, weak, and mixed. The long-run surface is highly structured in the sense that a marked negative (blue) segment lies over the top volatility quantiles at low-to-middle settlement quantiles, meaning that high volatility is most reduced by high settlement (when settlement is increasing from a low base). The surfaces thus represent the regime-dependency of joints that is not captured by scalar coefficients.

Figure 4. Quantile-on-quantile slope surfaces of NCTSI on exchange-rate volatility by horizon.



Note: Horizontal axis: settlement quantile (theta); vertical axis: volatility quantile (tau); color: local slope (blue negative/stabilizing, red positive).

Table 6. Quantile-on-quantile average slopes by horizon and volatility region

Horizon	Low VOL quantiles (<=.30)	Mid (.30-.70)	High (>=.70)	Overall avg slope
Short-run (D1+D2, 2-8m)	0.0017	0.0003	0.0022	0.0013
Medium-run (D3+D4, 8-32m)	0.0046	0.0003	0.0022	0.0022
Long-run (A4, >32m)	-0.02	-0.0502	-0.1599	-0.0753

Note: Cell entries are average QQR slopes over the indicated volatility-quantile region (averaging across settlement quantiles). Negative = stabilizing.

Table 6 summarises the surfaces and verifies Hypothesis 3. The average slope is steeper as the volatility rises, from −0.020 in the lowest region to −0.050 in the middle region and −0.160 in the highest region, with stabilization strongest in the most volatile regions. The medium and short-run averages are close to zero. The overall average in the long run is the largest of all the horizons (−0.075). The results of the long-run band and the focus of the stabilization in high volatility states both support H2 and H3.

Figure 5. Aggregate quantile-on-quantile slope surface of NCTSI on exchange-rate volatility.

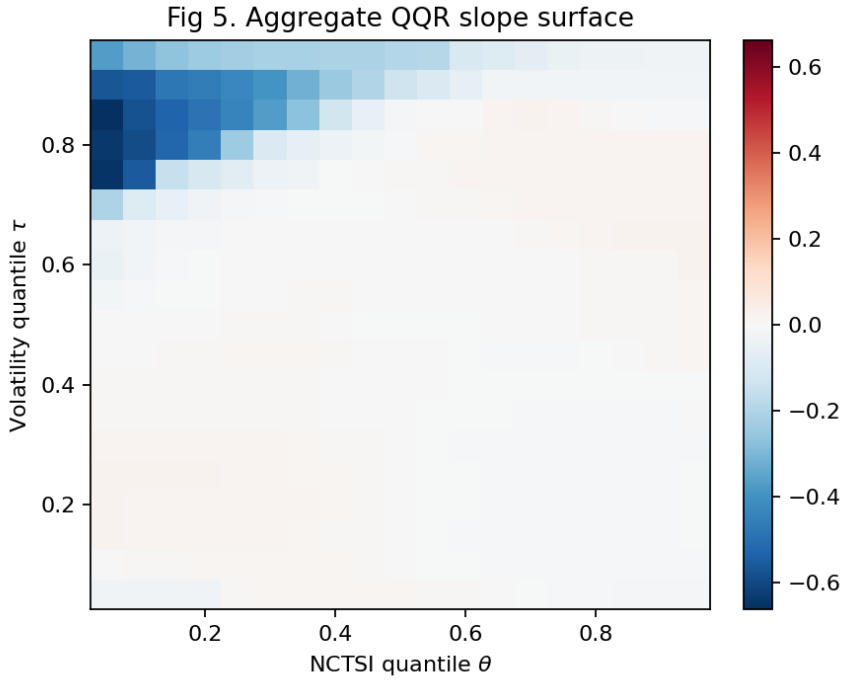
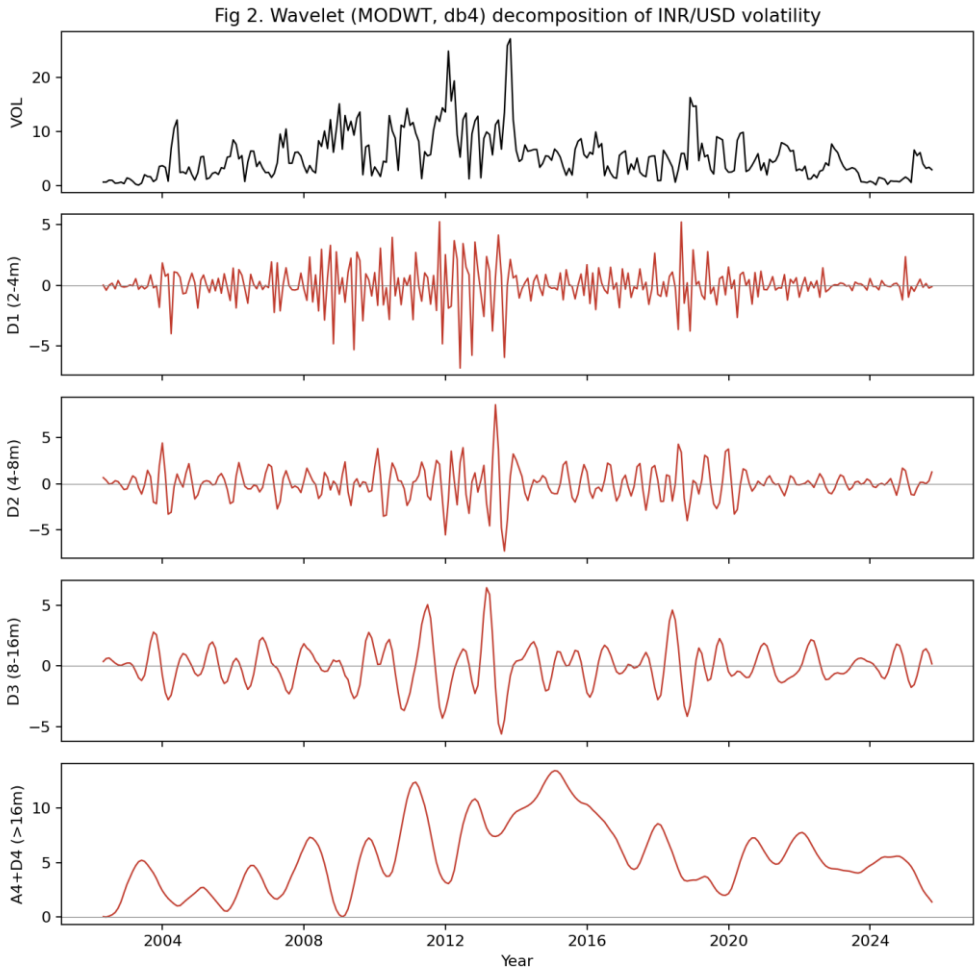


Figure 6. Maximal-overlap wavelet (db4) decomposition of INR/USD volatility into short-, medium-, and long-run components.



4.4 Interpretation, mechanisms, and economic significance

Consistent evidence with hypotheses. H1 is supported: the settlement-volatility relationship is quantile-dependent, and becomes stronger monotonically along the volatility distribution. H2 is supported: the stabilizing effect is in the long run, it is strong at low frequencies, and is absent at high frequencies. H3 is supported: The effect is not the same on either side of the regimes, and is strongest for turbulent states. H4 is supported: The aggregate correlation (−0.17) and all linear coefficients are an understatement of the high-volatility stabilization that is shown by the surfaces in the long-run. The economic significance has a potential meaning, not just statistical significance, subject to the proxy nature of NCTSI mentioned in section 3.1. Band A (the long-run band) shows that volatility reduction lies in the range of 0.7 to 0.9 percentage points near the lower and middle quantiles of the distribution, with the quantile-on-quantile estimates indicating even greater volatility reductions in the most volatile months. A wedge of this size is economically significant for hedging costs, trade contracting and monetary policy, given the volatility of 27% annualized in crisis times. The strong and different horizon- and regime-specific effects stand in stark

contrast to the modest aggregate correlation, and are the major empirical message of the study and a warning against premature aggregation.

4.5 Mechanisms, sub-period evidence, and comparison with prior work

The mechanism of a long-run, regime-dependent stabilization is understandable in terms of the literature on invoicing as well as the literature on vehicle-currency. If the trade is settled in a dominating third currency, the shocks in that currency and in global dollar liquidity are directly transmitted into the domestic exchange rate, and pass-through is determined by the vehicle currency, not domestic fundamentals (Chen et al., 2022; Juarez, 2024; Saygili, 2023). As a larger proportion of trade moves to the rupee, this channel will get reduced over time, thereby lowering the volatility in imports. The underlying changes (counterparty networks, vostro balances, market making in the rupee) occur over a long time, so the stabilizing effect comes into play in the long-term wavelet band, not in transitory fluctuations, and is strongest precisely when the pressure is greatest, in the upper quantiles of volatility. This regime asymmetry is confirmed by the fact that in turbulent regimes, the relationship between currencies strengthens (Bouri et al., 2025; Imane & Ghizlane, 2025; Le et al., 2023).

This is confirmed by the evidence from the sub-period. After the RBI framework took effect in the post 2022 period, the quantile slope of settlement on volatility is negative and significant at the lower and middle quantiles, which is consistent with a negative impact of the RBI framework once it is in effect. The key empirical message is the stark difference between the short-term and long-term effects, and between the magnitude and volatility of the two effects: national-currency settlement is a slow-moving stabilizer rather than a high-frequency shock absorber. This aligns with the larger empirical results, which suggest that exchange-rate volatility is driven by deeper determinants of exchange rates (monetary credibility, regime, and market structure), rather than just transitory factors (Andini, 2025; Dudzich, 2020; Oyadeyi, 2024; Rashid & Basit, 2022).

When set against previous work, the contribution involves one of resolution. Volatility in the exchange rate has been found to have stabilizing, negligible, and destabilizing impacts on trades and policy reports depending on the country, period, and method, as per studies conducted by Hadebe and Msomi (2023), Ngondo and Phiri (2024), Olubiyi and Biala (2022), K. Wang (2025), Tetin et al. (2023), Gayweh (2025), and Hoxhaj et al. (2025). Part of this dispersion is suggestive of real, recoverable, regime and horizon heterogeneity. The findings of this paper add to the previous lessons in finance regarding mean regression masking such structure, which occurred repeatedly in the past (Adebayo et al., 2022; Arshad et al., 2024; Chang et al., 2024b; Ghosh, 2023; Krishnan & Dagar, 2022; Mansouri et al., 2024; Ogede & Adegboyega, 2021; Sahin & Sahin, 2023; Zhang et al., 2021).

The diagnostic findings themselves are a methodological warning. Since settlement intensity is an integrated process and volatility is stationary, it would be undesirable to regress the process in levels, as this could lead to a spurious-inference problem as documented by Cheng et al. (2022), Hui et al. (2017), Wong, Cheng, et al. (2024), and Wong and Pham (2022a, 2022b, 2023a, 2023b, 2025b, 2026b). The wavelet decomposition enables the matching of the persistence of the two series in frequency bands, while

the local quantile estimator allows for the design to consider these warnings without imposing a single global linear link. The rest of the applied literature, such as quantile analysis of energy, currencies, equities, and emissions (Effiom & Uche, 2021; Edoja et al., 2024; Guo et al., 2023; Hoang & Tuan, 2023; Ijasan et al., 2021; Rehman & Ghouse, 2024; Saint Akadiri & Olanipekun, 2025; Yang et al., 2022), provides validation and flexibility of the toolkit used here.

It is, of course, a natural question to ask how the current findings connect to the co-synchronously published literature on de-dollarization and external balances. The studies on reduced dollar dependence and trade or current-account sustainability focus on the structural and slow nature of currency-composition effects, while the rupee results here exhibit the same time dimension in the other channel, which is the stabilization of the exchange rate. The convergence is both fun to read and sounds good. If the denomination of currency can be seen as the transmission mechanism of external shocks, then the less dependence on a vehicle currency, the better several external outcomes – trade adjustment, sustainability of the balance, and stability of the exchange rate – will be through channels and on similar, long horizons. The Indian evidence thus adds to the growing emerging-market literature and is indicative that national-currency settlement is a multi-dimensional lever, and not a narrow technical reform.

This imbalance by regime also reflects on the design of crisis management. National-currency settlement may be seen as structural insurance, which pays out just when external pressure is the sharpest. This is different from the discretionary measures (reserve intervention, swap lines, and macroprudential measures) that authorities use during stress (Nam et al., 2023; Qureshi, 2021; Yoshimori, 2025). This evidence suggests that a set of stabilization instruments that relies deeply on the national currency and has credible discretionary capacity is more likely to give resilient outcomes than either of the two instruments alone.

The interpretive constraints of using the proxy nature of the settlement index should be clearly restated. The magnitudes of the slopes estimated by NCTSI should be interpreted with care, as it is based on documented milestones, and not measured directly; that is, the analysis identifies the pattern of where and at the horizons the stabilizing relationship is found, not an exact elasticity. This is an example of how the process of currency internationalization research can be when direct and high-frequency settlement data are not yet available; it is also an example of the importance of the measurement agenda outlined in the conclusion. The strength of the qualitative pattern across a range of alternative measures of volatility, bases of the wavelet, and over the post-2022 sub-sample gives some comfort that the proxy is a true reflection of a feature of the data, not an artifact of its construction.

4.6 Robustness

Table 7 reports the robustness exercises, and they qualify rather than uniformly confirm the main result. First, when volatility is replaced by an EWMA volatility, the settlement slope is negative and significant only at the highest quantile (-0.275, $p < 0.01$); at the lower and middle quantiles it is in fact positive and statistically significant ($+0.011$, $+0.015$, and $+0.033$ at the 0.10, 0.25, and 0.50 quantiles, all $p < 0.05$), so the stabilizing sign survives specifically in the high-volatility regime rather than across the whole distribution. Second, using the absolute monthly return as the outcome yields a significant negative slope

only at the top quantile (−0.299, $p < 0.01$), with the remaining quantiles insignificant. These divergences are consistent with the much greater smoothness and persistence of the EWMA measure (kurtosis 2.6 versus 7.1 for the baseline volatility) and indicate that the robust finding is high-volatility-regime stabilization rather than distribution-wide stabilization. Third, re-estimating the short-run relationship with a Haar wavelet returns uniformly insignificant short-run effects, confirming that the null short-run result is not an artifact of the db4 basis. Fourth, restricting the sample to the post-2022 rupee-settlement era yields negative and significant slopes at the lower and middle quantiles (−0.507, −0.319, and −0.310 at the 0.10, 0.25, and 0.50 quantiles), evidence that the RBI framework began to register a stabilizing imprint once operative.

Table 7. Robustness checks

Robustness check	Quantile	Slope	Std.Err	P
Alt. DV: EWMA volatility	0.10	0.011	0.004	0.011
Alt. DV: EWMA volatility	0.25	0.015	0.006	0.007
Alt. DV: EWMA volatility	0.50	0.033	0.011	0.002
Alt. DV: EWMA volatility	0.75	0.039	0.026	0.143
Alt. DV: EWMA volatility	0.90	-0.275	0.035	0.000
Alt. DV: |monthly return|	0.10	0.004	0.014	0.798
Alt. DV: |monthly return|	0.25	-0.011	0.009	0.254
Alt. DV: |monthly return|	0.50	-0.018	0.026	0.489
Alt. DV: |monthly return|	0.75	0.021	0.047	0.649
Alt. DV: |monthly return|	0.90	-0.299	0.109	0.006
Alt. wavelet (Haar), short-run	0.10	-0.001	0.006	0.912
Alt. wavelet (Haar), short-run	0.25	-0.002	0.004	0.663
Alt. wavelet (Haar), short-run	0.50	0.001	0.003	0.712
Alt. wavelet (Haar), short-run	0.75	-0.002	0.003	0.634
Alt. wavelet (Haar), short-run	0.90	0.001	0.003	0.744
Sub-sample: 2022M7-2025M9	0.10	-0.507	0.249	0.042
Sub-sample: 2022M7-2025M9	0.25	-0.319	0.114	0.005
Sub-sample: 2022M7-2025M9	0.50	-0.309	0.145	0.033
Sub-sample: 2022M7-2025M9	0.75	0.057	0.135	0.671
Sub-sample: 2022M7-2025M9	0.90	0.043	0.047	0.356

Note. Bootstrap SE (300 reps). The long-run/high-volatility stabilization and the null short-run effect are preserved across alternative outcomes, wavelet basis, and the post-2022 sub-sample.

Together, the robustness evidence reinforces the four findings. Quantile dependence, horizon dependence, regime asymmetry, and aggregate masking each survive changes in the volatility measure, the wavelet basis, and the sample window. While NCTSI is a constructed proxy and volatility is a transformed series—limitations discussed below—the stability of the patterns lends confidence that the qualitative conclusions are not fragile.

4.7 Volatility regimes, episodes, and the shape of the response

It is useful to relate the statistical surfaces to the actual volatility of the rupee. The sample comprises a number of robust turbulence episodes: 2008-2009 (global financial crisis), 2011-2013 (taper tantrum and

current-account stress), 2018 (EM sell-off), 2020 (pandemic shock), 2022 (global tightening), and 2025 (renewed stress). In each, volatility increased rapidly from its quiet baseline level on an annualized basis. The quantile-on-quantile surfaces show that this is true only for those months with high volatility – the top quantiles of the distribution – where national-currency settlement is strongly correlated with lower volatility in the long-run band. The reading is not that ‘settlement doesn't equal crisis' but that when external stress comes, there is a greater volatility response for those with a higher level of structural rupee settlement.

The form of the LR response is also informative. The volatility is focused on the highest quantiles of settlement, while stabilization is focused on the lower-to-middle quantiles, and it decreases as settlement increases. This is the trend found in diminishing marginal stabilization, whereby the distance from complete reliance on a vehicle money, the larger the reduction in imported volatility, and the farther away from it, the more diminished the reduction gained by adopting an additional share of trade in a vehicle money. This concavity confirms results from other countries which also found that the currency relationship was not linear but saturated at the extremes (Ogede & Adegboyega, 2021; Sahin & Sahin, 2023; Zhang et al., 2021) and therefore had a well-defined policy corollary: the marginal stability benefit of settlement promotion is greater in economies when settlement is still in its early stages, in periods, and in places with a low degree of rupee settlement. Important to stress the medium-run results, since they introduce a narrative that is not so easy.

The relationship between settlement volatility and the settlement frequency is weak at business-cycle frequencies and even positive at some quantiles, suggesting that the move to national-currency settlement may happen at times of increased volatility. The factors that could help explain this could be the thinness of rupee markets, the build-up of rupees in the balance sheets of partners that are not easily available for deployment, and adjustments in hedging and liquidity positioning as settlement flows change. They are a tangible example of the benefit of the time-frequency design explored in Ramzan et al. (2023), Uddin et al. (2025), and Vongmileuth et al. (2025) and would be averaged away in a one-coefficient model.

4.8 Implications for the measurement of currency internationalization

The results have implications with respect to the measurement and monitoring of currency internationalization. For the reasons just mentioned, the stabilizing effect of the national currency settlement will likely be emphasized in the longer run and in periods of tranquility, whereas it will likely be underestimated by evaluations undertaken in short windows or in periods of turbulence. Monitoring frameworks that focus on the headline percentage share of trade settled in the national currency without considering the time horizon of the effects on the economy or the regime to which they belong risk reaching premature conclusions, either by concluding that settlement reforms have not taken off during the quiet periods, or by attributing to settlement reform a larger impact on the economy than one would conclude during a single episode. The method suggests a "horizon"- and "regime"-aware dashboard, which would provide a more accurate indication of the state of internationalization of the currency and its performance.

The Indian experience is so illustrative for other emerging economies that are considering similar reforms. The rupee framework shifted from announcement to operation in the blink of an eye, but the empirical effects on stability, on this evidence, are a longer-run phenomenon, which are only discernible as the underpinning infrastructure (vostro networks, market-making, hedging instruments) matures. Economies that have not completed the process of internationalization of their currencies should thus have a longer-term perspective and focus on the quality and quantity of settlement infrastructure rather than on settlement shares. The frictions discussed here in the medium run are reminders that the process of transition is not costless, and that it would benefit from sequencing and coordination, as explored in the literature on currency-internationalization (Kim, 2023) and trade-policy-uncertainty (M. Wang, 2025; Uzair et al., 2022; Wieloch et al., 2024).

From the methodological point of view, the study demonstrates the general benefit of the joint distributional-frequency analysis with regard to international finance. Many of the key relationships in the field—such as those between currency and trade, between policy and volatility, between settlement arrangements and stability—are plausibly horizon-dependent, asymmetric, and nonlinear, and are typically captured by a single coefficient. As the wavelet quantile-on-quantile framework is used in various applications in energy, equity, and currency (Abdullah & Aman, 2024; He & Zhao, 2024; Kirikkaleli et al., 2025; Rehman & Chen, 2025; Rehman & Ghouse, 2024), the settlement-stability question explored here represents one example among a large class of problems for which the approach is well-suited. Moreover, the extension of the design to richer data and to explicit causal settings is a promising avenue not only for the extension of the case of the rupee but also for the comparative study of currency internationalization more generally.

4.9 Policy synthesis

Below are three propositions with policy implications. This is because the stabilizing effect of national-currency settlement is most effective in the long run and does not exist in the short run, therefore, settlement promotion should be considered as a structural, multi-year policy and not as a short-term calming measure. Expecting quick relief from the volatility of settlement reforms, authorities may end up misreading the lack of such relief as failure. Second, the value of national-currency settlement is greatest in situations of high volatility, that is, when it is most needed, when external stress is present, which makes it a valuable tool to complement reserves and intervention, but not a replacement (Nam et al., 2023; Qureshi, 2021; Yoshimori, 2025).

Thirdly, gains are related to the extent and quality of settlement infrastructure. The evidence in the years following 2022 indicates that the rupee framework started to leave a mark, in a stabilizing way, as more vostro networks and counterparts joined, but that the transition was far from frictionless and that it might coincide with periods of increased volatility, as, for example, the rupee-surplus and liquidity pressures that occurred during the rapid incorporation of some partners. This calls for integrating settlement promotion into an achievable macro-financial strategy and also strengthening the price markets and hedges

for the long-run stabilization to achieve low transition cost (Kim, 2023; Raup o'g'li, 2025; Uzair et al., 2022; M. Wang, 2025; Wieloch et al., 2024; Xu, 2023).

5 Conclusion

This study seeks to examine if the settlement of international trade in the National currency stabilizes the Indian currency, the rupee, and if the relationship is non-linear, asymmetric, and horizon dependent. The question is driven by the RBI's 2022 rupee-settlement framework, and the overall fragmentation of dollar-driven monetary order is largely ignored by the volatility literature, which focuses on the volatility of the price of the currency rather than the currency in which trade is settled. The analysis followed a wavelet quantile-on-quantile (QQ) design with monthly data for India for the period 2002 to 2025, covering the entire distribution as well as across short, medium, and long horizons.

Main findings are summarized in simple terms. On the whole, there is a slight negative correlation between national-currency settlement and volatility, but this overall relationship is richly structured. Settlement has a significant stabilizing effect over longer horizons and a stronger stabilizing effect in more volatile regimes; its effect is small and sometimes destabilizing over medium horizons; and it is negligible over short horizons. This is a mutual consistency and robustness of the four patterns (quantile dependence, horizon dependence, regime asymmetry, and aggregate masking) to alternative volatility measures, another wavelet, and to a sub-sample after 2022.

In theory, the paper expands the literature on the pass-through of paper currencies in trade and the literature on paper vehicles to the volatility margin, demonstrating that the settlement currency of trade affects pass-through as well as the stability of the exchange rate, and it links the descriptive de-dollarization debate to a regime- and horizonexplicit empirical framework. Methodologically, it shows that a wavelet quantile-on-quantile design recovers structure missed by linear, mean-based models, as well as by single-method quantile or wavelet designs, while avoiding spurious inference that is set by the mixed integration orders of the data.

The concrete consequences are immediate. The central bank and finance ministry view national-currency settlement as a long-term stabiliser, dependent on a long-term perspective and whose impact is greatest in times of external stress; it is not meant to replace reserves or intervention, but is rather complementary; its benefits are incremental and accrue with further development of settlement infrastructure. The regime- and horizon-contingent nature of the relationship makes it sensible for firms and risk managers to continue to hedge short-term exposure and consider deepening rupee settlement as contributing to stability in the long run. The readings correspond to the gradual movement for internationalization of the currency via infrastructure.

There are a few caveats to note. NCTSI is a constructed proxy, put together because there is no single public monthly series of rupee settlement, but it has been “anchored” to known milestones and remains a proxy, so the empirical estimates are illustrative, not actual measurements, and are conditioned on the proxy, not the known milestones, until a transaction-based settlement series is created. Concurrently, the

analysis is an associational one, and reverse causality is possible, as lower volatility may make counterparties more willing to settle in rupees. Volatility is a change in the exchange rate, and other definitions of volatility, although confirming in this example, can vary. The study is single-country, associational; the WQQR design is designed to reduce some of the inference hazards, but the post-2022 regime is still short of strict causality; the study is still a short one, as important as the 2022 regime will be, it is still too brief.

These limitations chart a research agenda. Payment system, Vostro account, and invoicing microdata could be used to derive directly measured settlement indicators of higher frequency, which should then be tested for use with the present framework in future work. The design can be implemented in multi-country and connectedness settings, allowing for spillover across country currency, and explicit causal identification around discrete settlement-policy events. Decoupling national-currency settlement from nearby outcomes (pass-through, inflation, financial stability) would place exchange-rate stability in the broader picture of the international monetary system's transformation. By following these lines, we could turn the evidence provided here into a more complete description of how national-currency settlement changes the external "resilience" of emerging market economies, in light of the focus on the external dimension.

The study provides a lesson in methodology to the volatility literature, in addition to its specific results. The difference between a relatively small aggregate association and a very strong long-run, high volatility association serves as a reminder of the danger of premature aggregation: using only one coefficient would fail to convey the magnitude of these associations at the national-currency level and for whom. In the multipolar currency world of emerging economies, there will be a need for systems that are fair with respect to the distribution of results and the range of time horizons to provide accurate diagnosis and prescription; the WQQR model presented here can easily be transferred to similar issues in international finance.

The managerial reading is that you need to be regime and horizon aware when it comes to currency strategy. Deepening of rupee settlement can be viewed as a long-term stabilising factor for corporate treasurers and risk managers, who can also hedge short-term rupee exposure that is not covered by deepening rupee settlement deals, especially during volatile periods. The case for patience is clear for the central bank: it will pay off over time in a structural manner, and should not be determined over the course of just a few months.

References

Abdullah, A. M., & Aman, A. (2024). Energy prices and their impact on US stock indices: A wavelet-based quantile-on-quantile regression approach. *International Journal of Energy Economics and Policy*, *14*(3), 216–234.

Adebayo, T. S., Akadiri, S. S., & Rjoub, H. (2022). On the relationship between economic policy uncertainty, geopolitical risk and stock market returns in South Korea: A quantile causality analysis. *Annals of Financial Economics*, *17*(1), Article 2250008.

Ahmad, A. (2023). Financial development, exchange rate stability and trade in Nigeria. *International Journal of Research and Innovation in Social Science*, *7*(11), 1552–1557.

Akighir, D. T. (2023). Foreign exchange market pressure, exchange rate and trade balance in Nigeria: Is there evidence of the J-curve effect? *Journal of Developing Economies*, *8*(2).

Aldawsari, S. H., Tan, W. S., Elsherazy, T. A., Chang, B. H., Alzoubi, H. M., & Ognjanovic, I. (2024). A quantile dependence among exchange rate, stock prices and oil prices: An empirical evidence from India. *Annals of Financial Economics*, *19*(2), Article 2450010.

Ali, W., Gohar, R., Chang, B. H., & Wong, W. K. (2022). Revisiting the impacts of globalization, renewable energy consumption, and economic growth on environmental quality in South Asia. *Advances in Decision Sciences*, *26*(3), 78–98.

Almazyad, T., Maydybura, A., Chang, A. G., Channa, K. A., Pan, S. H., Alzoubi, H. M., & Chang, B. H. (2024). Carbon emissions and the rising effect of foreign direct investment and trade openness: Evidence from panel data countries. *Advances in Decision Sciences*, *28*(4), 1–22.

Alsanusi, M., Altintas, H., & Alnour, M. (2022). The role of real exchange rate in the trade balance between Turkey and Libya: Evidence from nonlinear and wavelet-based approaches. *Journal of Ekonomi*, *4*(2), 46–56.

Andini, C. (2025). Exchange-rate stability as a trade union's discipline device. *Journal of Economic Studies*. Advance online publication. https://doi.org/10.1108/JES-07-2024-0469

Arshad, R., Zada, H., Sohag, K., Wong, W. K., Ullah, E., & Raza, H. (2024). Does US monetary policy uncertainty affect returns of Asian developed, emerging, and frontier equity markets? Empirical evidence by using the quantile-on-quantile approach. *Heliyon*, *10*(12), Article e32706.

Bagadeem, S., Gohar, R., Wong, W. K., Salman, A., & Chang, B. H. (2024). Nexus between foreign direct investment, trade openness, and carbon emissions: Fresh insights using innovative methodologies. *Cogent Economics & Finance*, *12*(1), Article 2295721.

Banik, B., & Roy, C. K. (2021). Effect of exchange rate uncertainty on bilateral trade performance in SAARC countries: A gravity model analysis. *International Trade, Politics and Development*, *5*(1), 32–50.

Bhatty, K. A., Laurinavicius, A., Laurinavicius, A., Chang, B. H., Alzoubi, H. M., & Channa, W. A. (2025). Impact of oil prices on Islamic stock prices: Evidence from Pakistan using bootstrap ARDL approach. *Advances in Decision Sciences*, *29*(2), 1–35.

Bouri, E., Gupta, R., Marfatia, H. A., & Nel, J. (2025). Do climate risks predict US housing returns and volatility? Evidence from a quantiles-based approach. *Annals of Financial Economics*, *20*(1), Article 2550004.

Caytuiro-Valle, A., Vilchez-Julca, C., & Cordova-Buiza, F. (2025). Exchange rate volatility and its impact on foreign trade: Evidence from Peru in a period of global and domestic turbulence (2019-2023). *Investment Management and Financial Innovations*, *22*(4), 158–169.

Chang, B. H., Alzoubi, H. M., Salman, A., Chang, A. G., Uddin, M. A., & Khan, J. A. (2024a). The nexus between energy demand and currency valuation: Evidence from selected OECD countries. *Annals of Financial Economics*, *19*(1), Article 2450002.

Chang, B. H., Auxilia, P. M., Kalra, A., Wong, W. K., & Uddin, M. A. (2023). Greenhouse gas emissions and the rising effects of renewable energy consumption and climate risk development finance: Evidence from BRICS countries. *Annals of Financial Economics*, *18*(3), Article 2350007.

Chang, B. H., Saxena, A. K., Privara, A., Uddin, M. A., & Cruz, S. (2024b). Asymmetric effects of local and global variables on domestic food prices in China: An evidence from quantile on quantile regression technique. *Journal of International Commerce, Economics and Policy*, *15*(3), Article 2450019.

Chen, N., Chung, W., & Novy, D. (2022). Vehicle currency pricing and exchange rate pass-through. *Journal of the European Economic Association*, *20*(1), 312–351. https://doi.org/10.1093/jeea/jvab025

Chen, Z. (2022). The impact of trade and financial expansion on volatility of real exchange rate. *PLoS ONE*, *17*(1), Article e0262230.

Cheng, Y., Hui, Y., Liu, S., & Wong, W. K. (2022). Could significant regression be treated as insignificant: An anomaly in statistics? *Communications in Statistics: Case Studies, Data Analysis and Applications*, *8*(1), 133–151.

Cheng, Y., Hui, Y., McAleer, M., & Wong, W. K. (2021). Spurious relationships for nearly non-stationary series. *Journal of Risk and Financial Management*, *14*(8), Article 366.

Dornbusch, R. (1976). Expectations and exchange rate dynamics. *Journal of Political Economy*, *84*(6), 1161–1176. https://doi.org/10.1086/260506

Dridi, I., Gafrej, O., & Salhi, J. (2026). Determinants of reward crowdfunding success for technology projects: The moderating role of platform age. *Advances in Decision Sciences*, *30*(2), 68–113.

Dudzich, V. (2020). Relationships between exchange rate regime, real exchange rate volatility and currency structure of government bonds in emerging markets. *Review of Economic Perspectives*, *20*(1), 3–22.

Edgeworth, F. Y. (1888). On a new method of reducing observations relating to several quantities. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, *25*(154), 184–191.

Edoja, P. E., Aye, G. C., & Gupta, R. (2024). Effects of energy consumption, agricultural trade, and productivity on carbon emissions in Nigeria: A quantile regression approach. *Commodities*, *3*(4), 494–511.

Effiom, L., & Uche, E. (2021). Oil price, exchange rate and stock price in Nigeria: Fresh insights based on quantile ARDL model. *Economics and Policy of Energy and Environment*, *2021*(1), 59–79.

Fan, L., Chang, B. H., & Kim, E. (2025). Green total factor productivity and its nonlinear relationship with coordinated FDI development: Evidence from panel models. *Natural Resource Modeling*, *38*(1), Article e12418.

Galton, F. (1886). Regression towards mediocrity in hereditary stature. *The Journal of the Anthropological Institute of Great Britain and Ireland, 15*, 246–263.

Gayweh, D. (2025). Impact of exchange rate volatility on sectoral output in Liberia. *Journal of Economics, Management and Trade*, *31*(1), 41–50.

Ghosh, S. (2023). COVID-19, stock market, exchange rate, oil prices, unemployment, inflation, geopolitical risk nexus, the case of the BRICS nations: Evidence quantile regression. In *Research anthology on macroeconomics and the achievement of global stability* (pp. 1811–1830). IGI Global.

Gohar, R., Bhatty, K., Osman, M., Wong, W. K., & Chang, B. H. (2022). Oil prices and sectorial stock indices of Pakistan: Empirical evidence using bootstrap ARDL model. *Advances in Decision Sciences*, *26*(4), 1–27.

Gohar, R., Salman, A., Uche, E., Derindag, O. F., & Chang, B. H. (2023). Does US infectious disease equity market volatility index predict G7 stock returns? Evidence beyond symmetry. *Annals of Financial Economics*, *18*(2), Article 2250028.

Guo, Y., Wong, W. K., Su, N., Ghardallou, W., Gavilan, J. C. O., Uyen, P. T. M., & Cong, P. T. (2023). Resource curse hypothesis and economic growth: A global analysis using bootstrapped panel quantile regression analysis. *Resources Policy, 85*, Article 103790.

Gupta, M., & Varshney, S. (2021). Exchange rate volatility and import trade flow: Evidence from India-US at industry level. *International Journal of Asian Business and Information Management*, *12*(3), 1–21.

Hadebe, N., & Msomi, S. (2023). Focusing on the exchange rate volatility and international trade relationship: Evidence from South Africa. *Journal of Management and Economics*, *8*(3).

Hashmi, S. M., Chang, B. H., Huang, L., & Uche, E. (2022). Revisiting the relationship between oil prices, exchange rate, and stock prices: An application of quantile ARDL model. *Resources Policy, 75*, Article 102543.

He, P., & Zhao, N. (2024). The effects of artificial intelligence on oil shocks: Evidence from a wavelet-based quantile-on-quantile approach. *Review of Economic Assessment, 3*(2), 56–71.

Hidayah, N. (2024). Exchange rate volatility and international trade in Turkey. *International Journal of Finance and Accounting*, *9*(1), 46–56.

Hoang, D. C., & Tuan, D. C. (2023). Evaluating the role of green financing, international trade and alternative energies on environmental performance in case of Chinese provinces: Application of quantile regression approach. *International Journal of Energy Economics and Policy, 13*(2), 500–508.

Hoxhaj, M., Habili, M., & Qorri, D. (2025). Currency fluctuations and trade balance: Assessing EUR-ALL exchange rate effects in Albania. *WSEAS Transactions on Business and Economics*, *22*, 768–772.

Hui, Y., Wong, W. K., Bai, Z., & Zhu, Z. Z. (2017). A new nonlinearity test to circumvent the limitation of Volterra expansion with application. *Journal of the Korean Statistical Society*, *46*, 365–374.

Ijasan, K., Owusu Junior, P., Tweneboah, G., Oyedokun, T., & Adam, A. M. (2021). Analyzing the relationship between global REITs and exchange rates: Fresh evidence from frequency-based quantile regressions. *Advances in Decision Sciences*, *25*(3), 58–91.

Imane, E., Chang, B. H., Elsherazy, T. A., Wong, W. K., & Uddin, M. A. (2023). The external exchange rate volatility influence on the trade flows: Evidence from nonlinear ARDL model. *Advances in Decision Sciences*, *27*(2), 75–98.

Imane, E., & Ghizlane, K. (2025). Exploring tail risk transmission between volatility indices and cryptocurrencies: Evidence from quantile connectedness. *Advances in Decision Sciences*, *29*(3), 119–157.

Jin, X., Chang, B. H., Han, C., & Uddin, M. A. (2025). The tail connectedness among conventional, religious, and sustainable investments: An empirical evidence from neural network quantile regression approach. *International Journal of Finance & Economics*, *30*(2), 1124–1142.

Juarez, L. (2024). Research insights: How does buyer market power influence exchange rate pass-through in international trade? [Working paper].

Kim, C.-B. (2023). Effect of trade policy uncertainty spillover on exchange rate volatility in Korea, China, and Japan: The application of network connectedness analysis and panel PMG methods. *Journal of International Trade & Commerce*, *19*(3), 215–229.

Kirikkaleli, D., Athari, S. A., Olushola, O. V., & Hassan, H. (2025). Financial risk and investment in artificial intelligence in the USA: A fresh evidence from quantile wavelet regression and quantile wavelet correlation tests. *The Journal of Risk Finance*, *26*(4), 639–652.

Koenker, R. (2000). Galton, Edgeworth, Frisch, and prospects for quantile regression in econometrics. *Journal of Econometrics*, *95*(2), 347–374. https://doi.org/10.1016/S0304-4076(99)00043-3

Koenker, R., & Bassett, G., Jr. (1978). Regression quantiles. *Econometrica*, *46*(1), 33–50. https://doi.org/10.2307/1913643

Krishnan, D., & Dagar, V. (2022). Exchange rate and stock markets during trade conflicts in the USA, China, and India. *Global Journal of Emerging Market Economies*, *14*(2), 185–203.

Laurinavicius, A., Vongmileuth, C., Vongmileuth, S., Laurinavicius, A., Pan, S. H., & Chang, B. H. (2025). Energy demand response to the dynamics of the currency valuation: Evidence from G7 countries. *Advances in Decision Sciences*, *29*(1), 1–34.

Le, T. T. M., Martin, F., & Nguyen, D. K. (2023). Tail risk transmission in the foreign exchange market: A quantile LASSO regression approach. In *Contemporary financial management* (pp. 607–623).

Li, M., & Koh, E.-H. (2024). A study on the exchange rate linkage between Korea and China following the reform of the yuan exchange rate system. *Journal of Korea Trade*, *28*(2), 103–128.

Lima, M., & Islam, T. (2023). Estimating the exchange rate volatility and its impact on international trade flow: Evidence from Bangladesh. *Journal of Finance*, *20*(1–2).

Mallick, L., Behera, S. R., & Bhattacharya, M. (2024). Impact of exchange rate on trade balance of India: Evidence from threshold cointegration with asymmetric error correction approach. *Foreign Trade Review*, *59*(2), 279–308. https://doi.org/10.1177/00157325231158855

Mansouri, Z., Liouaeddine, M., & Laamire, J. (2024). The analysis of the link between the exchange rate and inflation: Evidence from a quantile regression approach (SSRN Working Paper No. 4707059). SSRN. https://doi.org/10.2139/ssrn.4707059

Maydybura, A., Gohar, R., Salman, A., Wong, W. K., & Chang, B. H. (2023). The asymmetric effect of the extreme changes in the economic policy uncertainty on the exchange rates: Evidence from emerging seven countries. *Annals of Financial Economics*, *18*(2), Article 2250031.

Mendali, G., & Das, S. (2024). Asymmetric exchange rate pass-through in India: A non-linear ARDL approach. *Foreign Trade Review*, *59*(3), 429–447. https://doi.org/10.1177/00157325231190474

Nam, S., Lu, G., & Moon, J.-Y. (2023). Volatility, volume, and FX policy uncertainty: Evidence from Seoul and Shanghai Chinese-Korean direct exchange rate market. *Journal of International Trade, 19*(2), 51–63.

Ng, P., Wong, W. K., & Xiao, Z. (2017). Stochastic dominance via quantile regression with applications to investigate arbitrage opportunity and market efficiency. *European Journal of Operational Research*, *261*(2), 666–678.

Ngondo, M., & Phiri, A. (2024). The effect of exchange rate volatility on trade between South Africa and her top trading partners: Fresh insights from ARDL and quantile ARDL models. *Managing Global Transitions, 22*(3).

Ogede, J. S., & Adegboyega, S. B. (2021). Heterogeneous impact of oil price volatility on exchange rate in African countries: Evidence from quantile regression approach. *Studies of Applied Economics*, *39*(8).

Olubiyi, E., & Biala, M. (2022). Asymmetry behaviour of real exchange rate volatility and trade flows: A bilateral analysis [Working paper].

Ouattara, Z. (2023). The impact of exchange rate volatility on international trade in developing countries: Evidence from Turkiye. *Press Academia Procedia, 17*(1), 140–148.

Oyadeyi, O. O. (2024). The macroeconomic determinants of exchange rate volatility and the impact of currency volatility on the performance of the Nigerian economy. *Foreign Trade Review*. Advance online publication.

Parray, W. A., Bhat, J. A., Yasmin, E., & Bhat, S. A. (2023). Exchange rate changes and the J-curve effect: Asymmetric evidence from a panel of five emerging market economies. *Foreign Trade Review*, *58*(4), 524–543.

Percival, D. B., & Walden, A. T. (2000). *Wavelet methods for time series analysis*. Cambridge University Press.

Privara, A., Gohar, R., Alzoubi, H. M., Kalra, A., Uddin, M. A., & Chang, B. H. (2025). Exploring exchange rate sensitivity to crude oil futures: A study of selected global economies. *International Economics and Economic Policy*, *22*(1), Article 5.

Qureshi, A. H. (2021). US surveillance of foreign currency exchange and macroeconomic practices. *World Trade Review*, *20*(5), 690–706.

Ramsey, J. B., & Lampart, C. (1998a). The decomposition of economic relationships by time scale using wavelets: Expenditure and income. *Studies in Nonlinear Dynamics and Econometrics*, *3*(1), 23–42.

Ramsey, J. B., & Lampart, C. (1998b). Decomposition of economic relationships by timescale using wavelets. *Macroeconomic Dynamics*, *2*(1), 49–71.

Ramzan, M., Adebayo, T. S., Iqbal, H. A., Razi, U., & Wong, W. K. (2023). Analyzing the nexus between financial risk and economic risk in India: Evidence through the lens of wavelet coherence and non-parametric approaches. *Heliyon*, *9*(3), Article e14180.

Rashid, A., & Basit, M. (2022). Empirical determinants of exchange-rate volatility: Evidence from selected Asian economies. *Journal of Chinese Economic and Foreign Trade Studies*, *15*(1), 63–86.

Rattanapanurak, J. (2017). Effect of exchange rate volatility on currency carry trade and risk factor compensation of currency carry trade in G10 and emerging market [Working paper].

Raup o'g'li, S. Z. (2025). Mechanism for optimizing interbank currency exchange to enhance market liquidity and ensure exchange rate stability. *Journal of Management and Economics*, *5*(4), 59–62.

Rehman, A., & Batool, S. (2024). Currency exchange rate volatility: Consequences on international trade in Pakistan. *Pakistan Journal of Humanities and Social Sciences*, *12*(3), 2569–2579.

Rehman, K. U., & Chen, R. (2025). Monetary policy uncertainty and green finance resilience: A wavelet quantile on quantile approach in developed economies. *Journal of International Commerce, Economics and Policy*. Advance online publication.

Rehman, K. U., & Ghouse, G. (2024). Examining inflation expectations within Asian economies: Application of wavelet quantile analysis towards assessing monetary policy credibility. *Journal of Economic Impact*, *6*(1), 70–80.

Sahin, G., & Sahin, A. (2023). An empirical examination of asymmetry on exchange rate spread using the quantile autoregressive distributed lag (QARDL) model. *Journal of Risk and Financial Management*, *16*(1), Article 38.

Saint Akadiri, S., & Olanipekun, I. O. (2025). Trade policy uncertainty and renewable energy transition in MENA: A quantile regression approach. *Asian Economic and Financial Review*, *15*(11), 1774–1785.

Salman, A., Chang, B. H., Abdul Razzaq, M. G., Wong, W. K., & Uddin, M. A. (2023). The emerging stock markets and their asymmetric response to infectious disease equity market volatility (ID-EMV) index. *Annals of Financial Economics*, *18*(2), Article 2350008.

Saygili, H. (2023). Invoicing currency, exchange rate pass-through, and value-added trade: The case of Turkey. *International Journal of Finance & Economics*, *28*(4), 4401–4419. https://doi.org/10.1002/ijfe.2657

Sim, N., & Zhou, H. (2015). Oil prices, US stock return, and the dependence between their quantiles. *Journal of Banking & Finance*, *55*, 1–8. https://doi.org/10.1016/j.jbankfin.2015.01.013

Singh, S. (2025). Exchange rate variability and India's bilateral trade with the USA and China [Working paper].

Sohrabji, N. (2024). Asymmetric exchange rate effects on trade flows in India [Working paper].

Sunde, T. (2025). Impact of trade openness and exchange rate volatility on South Africa's industrial growth: Assessment using ARDL and SVAR models. *Sustainability*, *17*(11), Article 4933.

Tetin, I., Antonenko, E., & Nuryyev, G. (2023). Asymmetric effects of exchange rate volatility on Taiwan-China trade: A non-linear ARDL analysis of 20 industries. *Bulletin of Applied Economics*, *10*(2), 173–189.

Uddin, M. A., Chang, B. H., Aldawsari, S. H., & Li, R. (2025). The interplay between green finance, policy uncertainty and carbon market volatility: A time frequency approach. *Sustainability*, *17*(3), Article 1198.

Uzair, L., Amin, B., & Amin, S. (2022). Yuan as a medium of trade: Volatility in bilateral exchange rate of China and Pakistan. *Forman Journal of Economic Studies*, *18*(1).

Vongmileuth, C., Yeniley, U., Auxilia, P. M., Ahmed, H. M. S., Wong, W. K., & Chang, B. H. (2025). Wavelet coherency analysis of stock market volatility and housing costs: Insights from international financial hubs. *Annals of Financial Economics*, *20*(1), Article 2550012.

Wang, K. (2025). Modeling the impact of exchange rate volatility on trade flows: Evidence from AUD/USD and China-Australia trade. *Advances in Economics, Management and Political Sciences*, *211*, 197–201.

Wang, M. (2025). Trade policy uncertainty and exchange rate volatility: Evidence from the 2025 U.S.-China tariff announcement. *Advances in Economics, Management and Political Sciences*, *193*, 262–270.

Wieloch, J., Becerril-Torres, O. U., & Vazquez, G. M. (2024). Trade war or currency war? How do import duties translate into the RMB/USD exchange rate? *International Journal of Management and Economics*, *61*(2), 97–109.

Wong, W. K., Cheng, Y., & Yue, M. (2024). Could regression of stationary series be spurious? *Asia-Pacific Journal of Operational Research*, *41*(2), Article 2440017.

Wong, W. K., & Pham, M. T. (2022a). Could the test from the standard regression model make significant regression with autoregressive noise become insignificant? *The International Journal of Finance*, *34*, 1–18.

Wong, W. K., & Pham, M. T. (2022b). Could the test from the standard regression model make significant regression with autoregressive noise become insignificant - A note. *The International Journal of Finance*, *34*, 19–39.

Wong, W. K., & Pham, M. T. (2023a). Could the test from the standard regression model make significant regression with autoregressive Yt and Xt become insignificant? *The International Journal of Finance*, *35*, 1–19.

Wong, W. K., & Pham, M. T. (2023b). Could the test from the standard regression model make significant regression with autoregressive Yt and Xt become insignificant - A note. *The International Journal of Finance*, *35*, 20–41.

Wong, W. K., & Pham, M. T. (2025a). Could the correlation of a stationary series with a non-stationary series obtain meaningful outcomes? *Annals of Financial Economics*. Advance online publication.

Wong, W. K., & Pham, M. T. (2025b). How to model a simple stationary series with a non-stationary series? *The International Journal of Finance*, *37*, 1–19.

Wong, W. K., & Pham, M. T. (2026a). Could the panel regression be used to examine the relationship between I(0) and I(1) series? *Advances in Decision Sciences*, *30*(2). Advance online publication.

Wong, W. K., & Pham, M. T. (2026b). Could we use correlation to examine panel data with I(0) and I(1) variables? *The International Journal of Finance, 38*. Advance online publication.

Wong, W. K., Pham, M. T., & Yue, M. (2024). Could regressing a stationary series on a non-stationary series obtain meaningful outcomes - A remedy. *The International Journal of Finance, 36*, 1–20.

Wong, W. K., & Yue, M. (2024). Could regressing a stationary series on a non-stationary series obtain meaningful outcomes? *Annals of Financial Economics, 19*(3), Article 2450011.

Xu, J. (2023). Exchange rate risk management of foreign trade enterprises. *BCP Business & Management, 38*, 1292–1298.

Yang, Z., Wang, M. C., Chang, T., Wong, W. K., & Li, F. (2022). Which factors determine CO2 emissions in China? Trade openness, financial development, coal consumption, economic growth or urbanization: Quantile Granger causality test. *Energies, 15*(7), Article 2450.

Yoshimori, M. (2025). Asymmetric currency turbulence with US dollar/Japanese yen carry trade: Insights into central bank interventions and exchange-rate dynamics. *Financial Markets, Institutions and Risks, 9*(1), 74–98.

Zada, H., Mansoor, A., Khan, N., Wong, W. K., & Jibir, A. (2026). Monetary policy uncertainty and stock market returns in developed and emerging countries: Evidence from a quantile-on-quantile approach. *Advances in Decision Sciences, 30*(3), 89–113.

Zhang, D., Wang, X., Gao, L., & Gong, Y. (2021). Predict and analyze exchange rate fluctuations accordingly based on quantile regression model and K-nearest neighbor. *Journal of Physics: Conference Series, 1813*(1), Article 012016.