

# **Informational Uncertainty and Nonlinear Exchange-Rate Dynamics: A Quantum-Inspired Framework for INR/USD Volatility**

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## **Abstract**

The currently existing exchange rate models mainly incorporate currency fluctuations through macroeconomic variables including inflation, interest rate differentials, trade balances and monetary policies impact. While these frameworks have continuously provided explanations for long term exchange rate behavior, they increasingly continue to struggle with accounting for sudden non linear movements in emerging markets during instabilities, commodity shocks and quick informational changes. The Indian Rupee (INR) in focus since the post 2020 global economic environment has shown high sensitivity not only to macroeconomic fundamentals but also to investor sentiment, digital financial narratives, global uncertainty and the rate of information transfer across connected financial systems in the country.

This paper proposes a new conceptual framework called “Quantum Informational Currency Dynamics (QICD)” to explain this probabilistic and informational nature of exchange rate instability in emerging market economies. It aims to derive conceptually from quantum probability theory, behavioral finance and narrative economics. This study argues that the Indian Rupee behaves not only as a macroeconomic factor but also as an informational system constituting competing expectations, narrative interactions and uncertainty propagation. The paper introduces the Quantum Currency Instability Index (QCII) which is a composite framework designed to measure different periods of elevated informational instability using big components. These components comprise of commodity stress, narrative uncertainty, capital flow pressure and central bank stability.

Using the INR/USD Exchange rates between 2020-2025 as a case study, this research focuses on how geopolitical shocks, commodity inflation, Federal Reserve tightening cycles, and domestic financial narratives added up to the nonlinear currency dynamics in India. Instead of attempting to replace classical exchange rate theories, this study aims to support them by adding informational and behavioral dimensions into the understanding of emerging market currency volatility. The paper argues that informational uncertainties and narrative expectations play a big role in the exchange rate instability during crisis time periods and that upcoming macro-financial research should account for these interactions between economies, information systems and investor psychology.

# 1.1 Background of the Study

The growing interconnectedness of global financial systems has had a significant impact in altering the behavior of emerging market currencies. In recent years, exchange rate volatility has become influenced by factors apart from macroeconomic fundamentals by taking into account factors such as geopolitical uncertainty, digital information flows, investment sentiment and narrative flow around financial markets. These developments have challenged the capacity of explanations provided by current exchange rate models, especially during periods of crisis and high uncertainty risks.

The Indian Rupee (INR) is a part of an important case within this changing global financial environment. India remains heavily dependent on imported crude oil and external capital flows which makes the currency sensitive to commodity price shocks, fluctuations in global liquidity conditions and geopolitical developments. Between the time period of 2020 and 2025, the Indian economy went through several major disruptions including the COVID-19 pandemic, supply chain disruptions, global inflationary pressure, the Russia-Ukraine crisis, and monetary tightening by the United States Federal Reserve. These events created a significant amount of volatility in the INR/USD Exchange rate and exposed the vulnerabilities associated with the emerging financial systems which are in use.

The modern exchange rate theories such as Purchasing Power Parity (PPP), Interest rate Parity (IRP) and monetary models usually model rational market behavior and equilibrium adjustments over time. While these frameworks remain foundational in international economics, recent events related to financial instabilities have shown their limitations during periods of rapid market reactions. Exchange rates do not respond only to macroeconomic fundamentals but also to investor psychology, market narratives, digital information flows and geopolitical expectations. For example, during the COVID-19 pandemic and its subsequent inflationary shocks globally, exchange rate movements frequently exceeded what traditional macroeconomic variables could justify (Hussain, Bashir & Rehman, 2024)

Recent studies in behavioral economics and narrative economics have shown that market stakeholders are heavily influenced by psychological expectations, collective narratives, and uncertainty handling rather than solely focusing on rational economic calculations (Akerlof & Shiller, 2009; Shiller, 2019). Investor sentiment, speculative expectations, geopolitical fear and central bank communication play a vital role in shaping currency-market dynamics, mainly in economies which are emerging as in such cases the investor confidence can shift rapidly.

To address these limitations demonstrated by traditional systems, this study introduces a conceptual framework titled as “Quantum Informational Currency Dynamics (QICD)”. The framework applies quantum-inspired probabilistic thinking to model how informational uncertainties, narrative shifts, and non linear market expectations impact INR/USD currency rate

volatility. The study further proposes a measurement model termed as the “Quantum Currency Instability Index (QCII)” to analyze informational instability which is affecting the Indian Rupee within the determined time period of 2020 and 2025.

By using a mix of macroeconomics, behavioral finance, narrative economics and uncertainty modeling, this paper aims to contribute to an interdisciplinary framework for understanding emerging market currency dynamics in the modern information economy.

## 1.2 Problem Statement

Traditional exchange rate models mainly give explanations about currency movement using macroeconomic variables such as inflation differentials, trade balances, interest rates and policy interventions. While these frameworks continue to remain useful for understanding long-term exchange rate trends, they struggle to give a clear explanation of abrupt and non linear currency movements during periods of instability and financial uncertainty in an economy.

Recent events involving the Indian Rupee have shown the extent of these limitations. During the COVID-19 Pandemic and Russia-Ukraine conflict, the INR/USD exchange rate systems showed a large amount of volatility before shifts occurred in the traditional macroeconomic indicators. Financial markets reacted rapidly to uncertainty, geopolitical developments globally, investor fear and differing narratives around inflation, commodity prices and global monetary closeness.

At the same time, the digitalization of financial information has increased the speed of the spreading of uncertainties across markets. Financial narratives are now being formed through online financial media social media platforms, algorithmic trading systems and real time geopolitical reporting. These informational systems increase investor reactions and sensitivity of emerging market currencies to uncertain shocks.

Despite these developments in the market, most exchange rate research remains heavily focused on macroeconomic variables while giving less attention to informational uncertainty, narrative propagation and stakeholder behavioral changes. The existing models fail to acknowledge investor expectations and informational instability interactions with the economic fundamentals during such crisis periods.

Furthermore, limited research has specifically examined the interactions within the context of emerging market currencies such as the Indian Rupee. This leads to the creation of a significant research gap in the understanding of informational systems and market driver uncertainties contributing to non linear exchange rate volatilities in developing economies.

The central gap remains in absence of an integrated framework capable of incorporating probabilistic decision frameworks into exchange rate analysis for emerging markets.

## 1.3 Research Aim

The primary aim is to examine the integration of informational uncertainties and narrative changes for providing a more effective explanatory system for non linear INR/USD Volatility than traditional macroeconomic exchange rate models.

The study also aims to develop:

- the Quantum Informational Currency Dynamics (QICD) framework; and
- the Quantum Currency Instability Index (QCII)

as tools for analyzing informational instability affecting the Indian Rupee/ United States Dollar volatilities.

## 1.4 Research Objectives

The study is guided by the following objectives:

- To critically evaluate the limitations of traditional exchange rate theories in explaining nonlinear INR/USD volatility during crisis time periods.
- To analyze the relationship between geopolitical uncertainty, commodity shocks, investor sentiment, financial narratives, and exchange-rate instability in India.
- To develop the Quantum Informational Currency Dynamics (QICD) framework for modeling uncertainty-driven currency behavior.
- To construct the Quantum Currency Instability Index (QCII) for measuring informational instability affecting the Indian Rupee.
- To examine major episodes of INR/USD volatility between 2020 and 2025 with the use of the proposed QICD framework and QCII model.

## 1.5 Research Questions

**RQ 1 :** How do geopolitical uncertainty and informational narratives impact INR/USD volatility?

**RQ 2 :** Can informational instability affecting the Indian Rupee be systematically measured using a composite index framework?

**RQ 3 :** Does the Quantum Informational Currency Dynamics (QICD) framework explain nonlinear currency movements more effectively than traditional macroeconomic models during time periods of crisis?

## **1.6 Research Hypotheses**

### **Hypothesis 1 :**

Periods characterized under high informational uncertainty are positively associated with increased INR/USD volatility.

### **Hypothesis 2 :**

Rapid changes in financial narratives and investor sentiment significantly impact instabilities in the Indian Rupee.

### **Hypothesis 3 :**

Combined informational indicators provide a stronger explanatory system for INR/USD volatility during crisis periods in comparison to the traditional macroeconomic indicators alone.

## **1.7 Scope of the Study**

This study focuses mainly on India and examines the INR/USD exchange rate changes between 2020 and 2025. This selected period is chosen effectively to capture multiple global disruptions including the COVID-19 pandemic, geopolitical crisis, commodity price shocks, inflationary pressures and international monetary tightening cycles.

The research concentrates on the interaction between:

- crude oil-price volatility,
- geopolitical uncertainty,

- financial-media narratives,
- investor sentiment,
- RBI communication,
- foreign institutional investment (FII/FPI) flows,
- capital-flow instability,
- and exchange-rate volatility.

From a methodological perspective, the study uses a mixed-method approach combining macroeconomic analysis, narrative dynamics, conceptual framework development and construction of an adaptive index. The research does not seek to predict future exchange rates precisely. Instead, it aims to understand how informational instability contributes to non linear currency changes within such emerging market economies with a focus on the Indian Economy.

Conceptually, the study aims to utilize a quantum inspired probabilistic reasoning and mathematical understanding. The research does not claim that literal quantum-mechanical systems can govern financial systems. However, it aims to establish that quantum concepts such as uncertainty, superposition, informational interaction and probabilistic collapse are used as analytical tools to model complex data driven market behavior.

## **2.1 Traditional Exchange-Rate Models**

The study of exchange rate determination has been continuously dominated by macroeconomic theories which explain currency movements by using relationships between national economic fundamentals in a country. Modern exchange rate models were initially developed from classical and neoclassical economic frameworks by emphasizing equilibrium adjustment mechanisms within international trade and monetary systems. Even though these models remain foundational in international economic theories, their limitations in explaining periods of an economy undergoing financial instability, speculative behavior and crisis driven volatilities has demonstrated several limitations at an application level.

### **Purchasing Power Parity (PPP)**

One of the earliest and most impact-led exchange-rate theories is the Purchasing Power Parity (PPP) model. This was originally developed by the “Law of One Price”. The PPP proposes that exchange rates adjust over time to equalize prices of identical goods across different countries. It suggests that currencies which are undergoing higher inflation should depreciate proportionately over time.

The relative PPP mathematical condition is represented as :

$$\Delta S \approx \pi_d - \pi_f$$

Where :

- $\Delta S$  represents exchange rate change,
- $\pi_d$  stands for domestic inflation,
- $\pi_f$  stands for foreign inflation.

PPP remains significantly influential in long run exchange-rate analysis because of constantly changing inflation differentials which contribute to gradual adjustments in the currency. Despite that, extensive empirical research has shown that PPP fails to provide explanations for short run changes in the exchange rate movements, mainly during periods of uncertainty in the economy and speculative capital movements (Rogoff, 1996).

In the Indian focus, the inflation rarely acts as an isolated explanation for abrupt fluctuations in its currency exchange rates with the United States Dollar. For example, time periods of rupee depreciation during the COVID-19 Crisis and the Russian-Ukraine conflict were strongly associated with commodity shocks, outflow of capital and global risk instead of being linked to inflationary reasons. This suggests that the market expectations and informational dynamics continue to increasingly influence and impact exchange rate behavior beyond PPP model's assumptions.

### **Interest Rate Parity (IRP)**

Interest Rate Parity (IRP) connects exchange rate calculations to differences in national interest rates. Based on this theory, investors should earn equal returns across countries after considering exchange-rates based adjustments. Within uncovered interest-rate parity, in several cases, expected currency depreciation offsets interest-rate advantages than considered generally.

The uncovered IRP condition is expressed as:

$$E(S_{t+1}) - S_t \approx i_d - i_f$$

Where:

- $E(S_{t+1})$  is the expected future exchange rate,
- $S_t$  is the current exchange rate,

- $i_d$  stands for the domestic interest rate,
- and  $i_f$  represents the foreign interest rate.

The IRP model assumes rational expectations, optimal market conditions and unrestricted mobility of capital. However, evidence indicates that exchange rates often vary from parity idealised conditions. This is seen majorly in emerging economies where investor sentiment and global uncertainty have a strong influence on capital dynamics.

India presents a useful example of these limitations seen in the IRP model. Even though interest rate differentials impact foreign portfolio-led investments, rupee volatility usually intensifies during periods of geopolitical unrest and financial stress irrespective of interest-rate conditions. This was also seen with the case of the PPP model. Recent studies on India's exchange rate regime under inflation targeting further shows that RBI intervention in such markets aims to neutralize excessive volatility rather than allowing just market-based adjustments.

## Monetary Models of Exchange Rates

During the 1970s, the development of monetary exchange-rate models was a step into joining macroeconomic monetary variables to the determination of the exchange rate. The models propose that the difference in the money supply, national income, inflation expectations and interest rates across economies will be reflected in exchange rates in modern economies.

A simplified monetary expression model can be shown as :

$$S_t = (M_d - M_f) - \beta(Y_d - Y_f) + \gamma(i_d - i_f)$$

Where :

- $M$  stands for money supply,
- $Y$  denotes economic output
- And  $i$  stands for interest rates

The monetary models were relevant since they related exchange rates to the policies of the central bank and the macro-economic equilibrium. Later emerging studies, however, showed that these models did not perform accurately in predicting short-term currency movements.

Monetary variables are insufficient to account for episodes of rapid depreciation of the Indian Rupee associated with oil prices shocks, foreign institutional investors' withdrawal or geopolitical tensions. External information factors like the Federal Reserve communication,

global risk perception and expectations of RBI intervention are becoming more important in the foreign exchange market in India.

### **Dornbusch Overshooting Model**

The overshooting model by Rudiger Dornbusch was a step forward since it added expectations and price rigidity to the study of exchange-rates. According to the model, changes in exchange rates overshoot long-run equilibrium levels in response to monetary shocks, and the rate of adjustment of the financial markets is greater than that of the goods markets.

The relationship can be shown as :

$$S' = \lambda(i - i^*)$$

Where exchange rate adjustment involves interest-rate differences between domestic and foreign economies.

The overshooting model has been especially influential as it acknowledged that short-term fluctuations in expectations and financial-market reactions can be larger than long-term fluctuations arising from equilibrium adjustments. The framework, however, still assumes somewhat rational and stable expectation formation.

A number of emerging markets today are more prone to reacting to foreign exchange events in a nonlinear fashion, owing to informational contagion, speculative storylines, and abrupt changes of investor sentiment. The kind of behavior it produces tends to be more complicated than the explanatory structure of the conventional overshooting models.

### **Limitations of Traditional Exchange-Rate Models**

Traditional exchange-rate models have been limited in several ways at the applied stage. There are several limitations on the traditional exchange-rate models.

#### **1. Analysis of a single linear structure :**

The conventional models usually imply that there are fixed relationships between macroeconomic variables and the exchange rate, while in crises the relationships are often nonlinear and markets react drastically.

#### **2. Rational Expectations Assumption :**

The conventional theories usually assume rational investors in the context of efficient information. The research of behavioral finance has shown that fear, herd mentality and cognitive biases have a significant effect on financial markets.

**3. Informational dynamics are treated only to some extent :**

Financial narratives, geopolitical uncertainty, media sentiment, and investor psychology are seldom included in the framework of traditional frameworks.

**4. Weak short-term predictive capacity :**

Studies that take a more empirical approach have consistently shown that macroeconomic models poorly explain the exchange-rate short run volatility during crisis episodes.

**5. Lack of explaining market volatility in the emerging markets :**

The external shocks, speculation on the capital flow and propagation of uncertainty to the point of the emerging market currency, for example, Indian Rupee, are very sensitive.

These limitations offer a theoretical basis for examining other methods that are potentially capable of incorporating informational uncertainty and narration into the analysis of exchange rates.

## **2.2 Currency Crisis Theories**

Currency-crisis theories are developed mainly to give explanations for episodes of severe exchange-rate instability, speculative attacks, and financial contagion that traditional macroeconomic models were not able to adequately explain. These frameworks further expanded its application into exchange-rate analysis by incorporating investor expectations, market confidence, and financial-system vulnerabilities.

### **First-Generation Crisis Models**

First-generation crisis models which are associated with Krugman (1979) are used to explain currency crises as the result of unsustainable macroeconomic policies. Governments maintaining fixed exchange-rate systems while financing fiscal deficits by using monetary expansion causes depletion of foreign-exchange reserves. This makes devaluation the eventual outcome.

These models assume rational speculative attacks once investors are recognizing reserve inadequacy. Although first-generation frameworks explain several historical crises, still they are less effective and optimum in analyzing current flexible exchange-rate systems which are dynamic in nature including India's managed float regime.

## **Second-Generation Crisis Models**

Second-generation crisis theories focused on self-fulfilling expectations and investor psychology in particular. Obstfeld (1996) argued that market stakeholder expectations regarding future devaluation can in itself cause financial crises.

If investors collectively as a market community expect depreciation then capital outflows will intensify exchange-rate pressure on the economy which will finally lead to the increase in the likelihood of actual depreciation. As a result, expectations become impactful in directly influencing economic outcomes.

This analytical perspective is particularly relevant for emerging markets where investor confidence remains highly sensitive to uncertainties and geopolitical developments around the world and the economic community in focus.

## **Third-Generation Crisis Models**

Third-generation crisis theories emerged after the Asian Financial Crisis of 1997–1998 and turned its focus towards aspects like banking-sector fragility, external debt exposure, and volatile capital flows.

These models emphasized:

- short-term foreign borrowing,
- banking-sector weaknesses,
- currency mismatches,
- and sudden reversals of capital inflows.

For India, foreign institutional investment (FII/FPI) flows remain highly important in determining exchange-rate stability. During events of global uncertainty there is frequent triggering of capital withdrawals from emerging markets. This contributes to rupee depreciation and foreign-exchange volatility.

## **Limitations of Currency Crisis Models**

Although crisis theories have moved beyond traditional macroeconomics, their applied use still shows important limitations:

- limited integration of digital informational systems,
- weak treatment of media narratives,
- insufficient modeling of psychological contagion,
- and not enough available explanation of nonlinear informational increases.

## **2.3 Behavioral Finance and Narrative Economics**

Behavioral finance emerged as a critique of an existing assumption that investors behave fully rationally within efficient financial markets. Instead, behavioral approaches have its argument in the thesis that financial decisions are strongly influenced by psychology, emotion, heuristics, and collective community-led behavior.

### **Herd Behavior and Investor Sentiment**

Herd behavior occurs when investors replicate or follow broader market actions rather than following solely on independently conducted analysis. In foreign-exchange markets, herd-driven reactions can increase the volatility by building self-reinforcing cycles of buying or selling pressure in the economic market.

Emerging-market currencies are especially vulnerable because international investors often respond collectively to changes in global risk sentiment.

### **Fear Propagation and Financial Contagion**

Behavioral-finance research demonstrates that uncertainty and fear spread rapidly during crises. Negative news regarding inflation, geopolitical conflict, banking instability, or recession risk can intensify capital outflows and speculative behavior.

The COVID-19 pandemic was an example of how uncertainty propagation increased the speed of exchange-rate volatility across emerging markets which was also seen in India.

### **Narrative Economics**

Narrative economics was developed by Robert Shiller. It argues that economic outcomes are impacted by viral stories and collective interpretations and perspective-based analysis of events.

Narratives surrounding:

- inflation,
- central-bank credibility,
- geopolitical escalation,
- commodity shortages,
- or recession fears

can strongly influence investor expectations and market behavior.

Recent research on RBI communication has given us an idea that central-bank language significantly also affects market expectations and financial sentiment in a country like India.

Studies that utilised textual analysis and natural-language processing showed that RBI communication contains measurable informational signals which can in fact influence investor behavior and general reactions in the market of the stakeholders.

## **Informational Markets and Digital Finance**

The rise of digital financial communication has completely changed financial markets into highly interconnected informational ecosystems. News platforms, algorithmic trading systems, financial influencers, and social media are increasing the speed of expectation formation among these ecosystems.

As a result, exchange-rate movements increasingly take into account the informational interpretation rather than just simply accounting for realized economic conditions.

## **2.4 Quantum Probability in Financial Decision Theory**

As alternatives to classical probability models, quantum probability models arose in cognitive science and behavioral decision theory as models for uncertainty and ambiguous decision making.

Importantly, Quantum inspired financial methods don't state that markets follow “literally quantum mechanics.” Instead of that, they use mathematical and conceptual tools based upon the quantum probabilistic framework to model complex expectation structures and uncertainty.

### **Superposition of Expectations :**

According to quantum-inspired approaches, decision makers can have a number of competing expectations prior to the resolution of uncertainty.

In the foreign exchange markets, traders can expect as a community at the same time:

- RBI intervention,
- rising oil prices,
- Federal Reserve tightening,
- geopolitical escalation,
- or capital inflows.

This existence of displaced expectations is similar to a probabilistic superposition.

### **Informational Uncertainty :**

The assumptions of many economic models are that probability distributions are fixed and information is processed rationally. Instead, quantum-inspired approaches regard uncertainty itself as a dynamic process, as more information becomes available.

This is especially important in today's financial landscape where expectations frequently change depending on the information coming out of the news and the geopolitical climate.

### **Non Linear Volatility Trends :**

Markets often swing quickly from periods of uncertainty to prevailing consensus reactions during difficult periods; for example, a period of volatility spikes. These shifts are comparable to shifts that “collapse” in terms of information, suddenly changing from one expectation to the other in a panic or in confidence.

Such nonlinear dynamics have come into more frequent play for emerging market currencies facing geopolitical shocks and informational contagion.

### **Significance of the present study:**

Quantum-inspired probability models are relevant to this research because they provide conceptual tools for understanding:

- nonlinear exchange-rate behavior,
- competing market expectations,
- informational ambiguity,
- and uncertainty propagation.

The properties contribute to the foundation for the development of the Quantum Informational Currency Dynamics (QICD) model that is presented in this paper.

### 3.1 Conceptual Foundation of QICD

The proposal of constructing the framework of the Quantum Informational Currency Dynamics (QICD) comes from the limitations existing within the conventionally used exchange-rate theories. QICD states a strong argument that the Indian Rupee should not be viewed only as a reflection of macroeconomic equilibrium. The Rupee now operated within a continuously evolving informational ecosystem where exchange-rate fluctuations are impacted by interactions between :

- macroeconomic fundamentals,
- geopolitical developments,
- investor expectations,
- financial narratives,
- central-bank communication,
- algorithmic information flows,
- and propagation of uncertainties.

The framework takes its principles from developments in behavioural economics, narrative economics, quantum probability theory and modelling of uncertainties. Most importantly, the QICD does **not** claim that literal quantum-mechanical processes should govern existing financial markets. Instead, the framework takes into account quantum inspired probabilistic models into its mathematical application to analyze complex expectation structures under conditions of differing crises. Such approaches have been seemingly used in new-age financial decision research, mainly, within the domain of quantum probability and quantum cognition.

The QICD framework as a result interprets exchange-rate behavior as a dynamic informational ecosystem which can be characterized by:

1. **Probabilistic expectation formation**

Investors work under uncertainty and continuously revise expectations as new information is brought to them.

2. **Narrative interaction**

Financial narratives play an important role in impacting collective interpretation of economic events and influence investor behavior.

3. **Informational amplification**

Digital media, algorithmic trading, and social communication increase the speed of uncertainty propagation across markets.

4. **Nonlinear market adjustment**

Exchange-rate instability forms an accumulation over time through informational stress before sudden volatility spikes occur.

### 5. **Expectation-driven volatility**

Markets often react to expected future conditions rather than current macroeconomic fundamentals which are existing.

The framework introduces four major theoretical frameworks which will fall within the QICD:

- **Informational Superposition**

Multiple competing market expectations coexist simultaneously before uncertainty resolves.

- **Narrative Dynamics**

Financial narratives influence investor sentiment and collective market interpretation.

- **Informational Decoherence**

Uncertainty collapses into dominant market consensus or panic following major informational shocks.

- **Nonlinear Currency Dynamics**

Informational stress accumulates gradually before triggering abrupt volatility spikes.

## 3.2 Informational Superposition

One of the main concepts within the QICD framework is Informational Superposition which was stated earlier. This is borrowed from the concepts in Quantum Probability Theory. Informational Superposition refers to the coexistence of multiple competing market expectations before the uncertainties are resolved.

In modern economic models which are being employed today, stakeholders are often assumed to hold stable expectations on rational processing of information available to them. However, in the applied world markets rarely operate within conditions of certainty. Investors regularly hold incomplete, contradictory and quickly changing information about future economic conditions.

Especially before major economic or geopolitical events take place these financial markets often contain several simultaneous and competing expectations regarding future outcomes.

Within the Indian foreign-exchange market, investors may at the same time anticipate:

- RBI intervention to stabilize the rupee,

- rising crude oil prices,
- aggressive U.S. Federal Reserve tightening,
- geopolitical escalation,
- capital inflows into Indian markets,
- or weakening global growth conditions.

These expectations exist together probabilistically within the market before new information is added and aims to bring consensus in the market.

The concept may be represented as:

$$\Psi = a_1 E_1 + a_2 E_2 + a_3 E_3 + \dots + a_n E_n$$

Where:

- $\Psi$  represents the informational expectation state of the market,
- $E_n$  represents competing expectations,
- and  $a_n$  represents the relative probability weight linked to each expectation.

Another key fact about QICD is that it does not treat these probabilities as fixed. Instead, these probabilities change dynamically as markets keep absorbing new information.

This perspective is especially relevant during periods of uncertainty because exchange-rate behavior often incorporates changing expectations rather than assumed economic outcomes which is usually seen theoretically. For example:

- oil-price rumors may weaken the rupee before actual commodity shortages emerge,
- anticipated Federal Reserve tightening may trigger capital outflows before policy implementation,
- and geopolitical fears may increase currency volatility before measurable economic damage occurs.

Within QICD, informational superposition encapsulates the pre-volatility phase of currency instability where uncertainty is accumulated through competing expectations through the different stakeholders.

## 3.3 Narrative Dynamics

The QICD framework states that financial narratives play an important part in determining exchange-rate dynamics because the interpretation of the economic event is not enough to make investment decisions, it is also influenced by the collective interpretation of the event.

Narratives are simple explanations of uncertainty through which financial markets navigate uncertainty. These narratives shape:

- investor confidence,
- Predictions on expected future policy,
- Predictions of economic security,
- Responses to geopolitical changes and reactions.

In narrative economics, differing economic perspectives and shared beliefs in the market have a strong impact on the outcome of the economy.

In the context of the Indian Rupee, this can depend on:

- inflation,
- RBI credibility,
- crude oil dependency,
- global recession fears,
- geopolitical conflict,
- or foreign-investment flows

can have a considerable effect on exchange-rate fluctuations.

For instance, the Russia–Ukraine war and the energy insecurity narrative and commodity inflation had a greater depreciation pressure on the rupee than just macroeconomic effects. Likewise, stories of Federal Reserve tightening cycles often increase worries about capital outflows from emerging markets.

Modern financial systems are informationally interconnected, and narratives are particularly potent. Nowadays, information is disseminated quickly via:

- financial news platforms,
- social-media finance communities,
- algorithmic trading systems,
- central-bank communication,
- and live geopolitical coverage.

As stories proliferate they influence investor psychology and the broader market's understanding.

The findings in recent research now indicate that RBI communication has a significant impact on financial-market expectations via the language tone as well as through forward guidance and policy signaling.

In QICD, narratives are thus considered not as a secondary market analysis but as a set of informing forces that can have a direct impact on exchange rates.

Narrative interaction is a contributor to:

- expectation amplification,
- fear propagation,
- speculative positioning,
- and volatility clustering.

Narratives can become self-reinforcing, creating feedback loops between investor behaviour and market outcomes, as uncertainty increases.

## 3.4 Informational Decoherence

Informational Decoherence is the idea that information uncertainty can be resolved into the prevailing market opinion after a big event or shock.

In times of informational superposition, there are several expectations which exist concurrently. But once the information turns crucial, markets quickly settle on prevailing understanding.

Some examples include:

- sudden RBI intervention,
- major geopolitical escalation,
- Central bank policy statements,
- banking-sector crises,
- or sudden changes in commodity prices.

In such cases, uncertainty is reduced and traders re-evaluate their trades in a hope of new refreshed expectations and market conditions.

In QICD, informational decoherence accounts for the sudden and disproportionate jumps in exchange-rate volatility.

Informational stress can build up over time, and leading up to a period of volatility, it can manifest as uncertainty and conflicting expectations. After a dominant narrative comes to the fore, markets quickly move towards panic or consensus responses.

This process contributes to:

- abrupt rupee depreciation,
- panic-driven capital outflows,
- speculative overshooting,
- and volatility spikes.

The decoherence process may be shown through:

$$\Psi \rightarrow E_k$$

Where:

- $\Psi$  represents competing expectation states,
- and  $E_k$  represents the dominant market expectation after informational collapse.

As a result, exchange-rate instability increasingly also has to capture informational synchronization rather than just capturing gradual macroeconomic adjustments.

## 3.5 Non-Linear Currency Dynamics

Typical exchange-rate models usually make the assumption of relatively smooth and proportional links between macroeconomic variables and exchange-rate movements. In reality, markets for foreign exchange often are nonlinear, showing the following features:

- sudden volatility spikes,
- abrupt depreciation episodes,
- panic-driven capital flows,
- and unexpected flips, flops and flips.

The QICD theory proposes that these nonlinear dynamics arise as a result of the building up of informational stress in financial systems.

In regular conditions, markets can absorb uncertainty based information without a significant spike in volatility. But as the informational pressure grows, due to geopolitical uncertainty, conflicting narratives, commodity shock or policy uncertainty, the market enters the boundary of instability.

Once those thresholds are reached, fairly sized informational shocks can lead to very large market responses. This nonlinear process is similar to the kind of behaviours that can be observed in complex systems: instability builds up slowly and gradually until a sudden structural adjustment takes place.

In the INR/USD universe, nonlinear volatility can arise due to the interaction between:

- crude oil-price shocks,
- FII redemption,
- RBI communication uncertainty,
- global monetary tightening,
- and geopolitical narratives.

The framework thus does not view exchange-rate instability solely as a linear manifestation of macroeconomic imbalance, but as an emergent phenomenon, caused by interaction and connectedness of informational processes.

QICD suggests that the growing volatility of exchange rates is nowadays more of a reflection of:

- probabilistic uncertainty,
- informational amplification,
- narrative contagion,
- and expectation-synchronizing the market.

This viewpoint is the basis for the forthcoming theoretical framework, the Quantum Currency Instability Index (QCII) that measures the informational instability of the Indian Rupee in the applied market use-case.

## **4.1 Introduction to the Quantum Currency Instability Index (QCII)**

In the previous chapter, the theoretical background of Quantum Informational Currency Dynamics (QICD) was introduced, which views the Indian Rupee as an informational system that can be affected by uncertainty, competing expectations, financial stories and geopolitical developments. The study suggests that, although QICD offers the theoretical basis, an analytical

tool that has a measurable analytical attribute is required for empirical analysis of informational instability within the INR/USD exchange-rate system.

To meet these needs, the present study suggests the *Quantum Currency Instability Index (QCII)*. The QCII is an original composite index that aims to calculate the level of informational instability of the Indian Rupee during the years 2020-25. The QCII goes beyond the traditional measurement of exchange rates based on just macroeconomic fundamentals and incorporates informational, narrative, geopolitical and financial-pressure measures in a single analytical framework.

The index is built based on the analysis that exchange-rate volatility in emerging markets incorporate the following:

- commodity shocks,
- investor expectations,
- financial narratives,
- capital-flow instability,
- and institutional communication.

Therefore, the QCII aims to measure the level of informational stress in the foreign-exchange market in India and test whether the periods of high informational instability are correlated with high INR/USD volatility.

One of the main original contributions of this research is that the development of the QCII is one of the few studies that tries to build a composite index focused at measuring the narrative-driven and informational instability of the emerging-market currencies.

## **4.2 Purpose and Objectives of QCII**

The main objective of the Quantum Currency Instability Index is to develop a systematic database for analysing informational instability of the Indian Rupee.

The QCII aims to:

- Identify periods of increased information uncertainty in the exchange-rate system INR/USD.
- Embed macroeconomic stress and informational effects in a coherent analytical model.
- Investigate if informational instability is correlated with high exchange rate volatility.
- Understand the relationship between narratives, capital flows, geopolitical shocks and the behaviour of currency markets and institutional credibility.
- Offer a conceptual and empirical instrument that can be used alongside traditional macroeconomic exchange-rate analysis.

The QCII is not primarily a short-term forecasting model, as are purely econometric forecasting models employed presently. In application, the index measures how stressful the interpretations of the market stakeholders are regarding the Indian Rupee in times of significant global activities.

### 4.3 Structural Design of the QCII

The Quantum Currency Instability Index is constructed using four major components:

1. Commodity Stress (CS)
2. Narrative Uncertainty (NU)
3. Capital Flow Pressure (CFP)
4. Central Bank Stability (CBS)

These components collectively represent the major informational and financial forces affecting INR/USD volatility within the QICD framework.

The structure of the QCII is represented conceptually as:

$$QCII = CS + NU + CFP - CBS$$

Where:

- **CS** = Commodity Stress
- **NU** = Narrative Uncertainty
- **CFP** = Capital Flow Pressure
- **CBS** = Central Bank Stability

The subtraction of CBS reflects the stabilizing influence of institutional credibility and effective monetary communication.

#### Explanation of Structural Logic

The QCII framework assumes that:

- Commodity Stress increases external macroeconomic pressure.
- Narrative Uncertainty amplifies informational instability.
- Capital Flow Pressure increases financial-system vulnerability.
- Central Bank Stability reduces informational panic and stabilizes expectations.

Therefore:

- Higher CS, NU, and CFP increase instability.

- Higher CBS decreases instability.

## **4.4 Component I — Commodity Stress (CS)**

### **4.4.1 Conceptual Foundation**

Commodity Stress: External macroeconomic and informational pressure due to price fluctuations in commodity markets (especially crude oil) on the international market.

India continues to be very dependent on imported energy commodities and international oil-price volatility is one of the most important factors of exchange-rate vulnerability. As the price of crude oil goes up, the prices of everything else goes up:

- import expenditure,
- current-account deficits,
- inflation expectations,
- and availability of U.S. dollars.

Hence the rupee is often devalued during the high commodity stress periods.

The disruption of commodity markets and how quickly this can escalate exchange-rate volatility in emerging economies was illustrated by recent global events, such as the COVID-19 recovery period and the war in Ukraine.

In the context of the QCII, Commodity Stress is considered as both:

- a macroeconomic pressure variable; and
- an informational instability trigger.

This is because oil-price shocks also shape investor perceptions about inflation and other economic and monetary measures of vulnerability.

## 4.4.2 Variables Included in Commodity Stress

Commodity Stress consists of the following variables:

| Variable                   | Purpose                                        | Data Source                                  | Frequency         |
|----------------------------|------------------------------------------------|----------------------------------------------|-------------------|
| Brent Crude Oil Prices     | Measures international energy-price volatility | U.S. Energy Information Administration (EIA) | Monthly           |
| Commodity Inflation        | Measures imported inflation pressure           | RBI / IMF                                    | Monthly           |
| Import Dependency Pressure | Measures India's external commodity dependence | Ministry of Petroleum & Natural Gas          | Monthly/Quarterly |

*Table 4.1 : Commodity Stress Variables*

## 4.4.3 Expected Relationship with INR/USD

Higher Commodity Stress is projected to contribute to:

- increased depreciation pressure on the rupee,
- inflationary expectations,
- current-account vulnerability,
- and higher exchange-rate volatility.

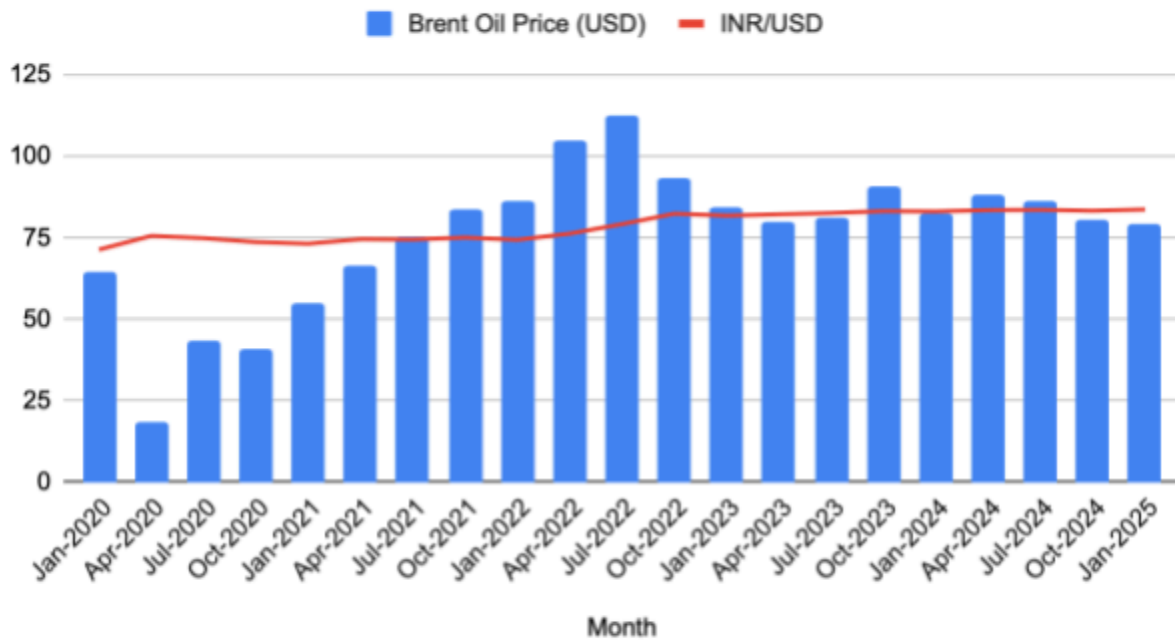
The relationship is expected to increase mainly during periods of geopolitical uncertainty affecting global energy markets and global economies.

This figure below visualizes the relationship between Brent crude oil price volatility and INR/USD exchange-rate movements between 2020 and 2025.

## 4.4.4 Empirical Visualization

The study will visually compare Brent crude-oil prices with INR/USD exchange-rate movements between 2020 and 2025.

## Brent Oil Price (USD) and INR/USD



**Figure 4.1 : BRENT CRUDE OIL PRICES VS INR/USD EXCHANGE RATE**

Source : U.S. Energy Information Administration (EIA); Reserve Bank of India (RBI)

## 4.5 Component II — Narrative Uncertainty (NU)

### 4.5.1 Conceptual Foundation

Narrative Uncertainty is an information instability that stems from competing financial narratives, geopolitical uncertainty, media sentiment, and expectation divergence in the financial market.

The traditional models of exchange rates tend to ignore the role of narratives in the investor behavior. However, from a behavioural finance and narrative economics perspective, collectively held stories and interpretations of economic events are strong drivers of financial markets.

Modern financial systems enhance narrative effects by means of:

- financial news networks,
- social-media finance communities,
- real-time market commentary,
- And algorithmic information dissemination.

As a result, stories have become a tool for shaping:

- investor confidence,
- speculative positioning,
- risk perception,
- and exchange-rate expectations.

For example:

- recession fears,
- banking-sector instability,
- geopolitical escalation,
- or expected Federal Reserve rate hikes.or expected Fed rate hikes.

may cause volatility in the exchange rate even in the absence of significant deterioration in macroeconomic indicators.

In the context of QCII, Narrative Uncertainty serves as a key information variable that can trigger market reactions that are stronger than the nonlinear response.

## 4.5.2 Variables Included in Narrative Uncertainty

| Variable                       | Purpose                                | Source              |
|--------------------------------|----------------------------------------|---------------------|
| Financial News Sentiment       | Measures positive/negative market tone | Reuters / Bloomberg |
| Geopolitical Headlines         | Measures geopolitical instability      | Reuters / IMF       |
| Analyst Expectation Divergence | Measures disagreement among analysts   | Financial reports   |
| RBI Communication Tone         | Measures monetary-policy uncertainty   | RBI speeches        |

**Table 4.2 : Narrative Uncertainty Variables**

### 4.5.3 Narrative Classification Framework

Narratives are manually classified into three categories:

| Classification | Meaning                               |
|----------------|---------------------------------------|
| Positive       | Optimistic market expectations        |
| Neutral        | Uncertain or balanced narratives      |
| Negative       | Fear-driven or instability narratives |

Examples of negative narratives include:

- “Global recession fears weaken emerging markets”
- “Oil-price surge intensifies inflation concerns”
- “Capital outflows pressure the rupee”

Examples of positive narratives include:

- “RBI reassures markets regarding liquidity”
- “India growth outlook remains resilient”
- “Forex reserves stabilize market sentiment”

| Date        | Headline                              | Classification |
|-------------|---------------------------------------|----------------|
| 12 Mar 2020 | “Pandemic fears weaken rupee outlook” | Negative       |
| 08 Jul 2021 | “RBI reassures liquidity stability”   | Positive       |
| 14 Sep 2022 | “Markets await Fed policy decision”   | Neutral        |

*Table 4.3 : Narrative Sentiment Classification Examples*

## 4.6 Component III — Capital Flow Pressure (CFP)

## 4.6.1 Conceptual Foundation

Capital Flow Pressure is a financial exposure due to the variations of foreign institutional investment, reserve position and global conditions of liquidity.

However, emerging-market currencies are more sensitive to global capital flows as investors quickly switch their capital investments when markets are uncertain.

A sharp slowing of economic growth within advanced economies often comes along with :

- foreign portfolio outflows,
- reserve depletion,
- and volatility in emerging-market exchange rates.

There was significant volatility in foreign investment in India during:

- the COVID-19 crisis,
- inflationary shocks,
- and the Fed Reserve's tightening cycles.

In the framework of QCII, Capital Flow Pressure reflects the “pressure” on the external liquidity conditions and vulnerability of the exchange rate.

## 4.6.2 Capital Flow Pressure Variables

**Table 4.4 : Capital Flow Pressure Variables**

| Variable              | Description                          | Source        |
|-----------------------|--------------------------------------|---------------|
| FII/FPI Outflows      | Measures foreign-capital withdrawals | NSDL          |
| Forex Reserve Changes | Measures reserve adequacy            | RBI           |
| Bond-Market Pressure  | Measures financial liquidity stress  | RBI/Bloomberg |

## 4.6.3 Expected Relationship with INR/USD

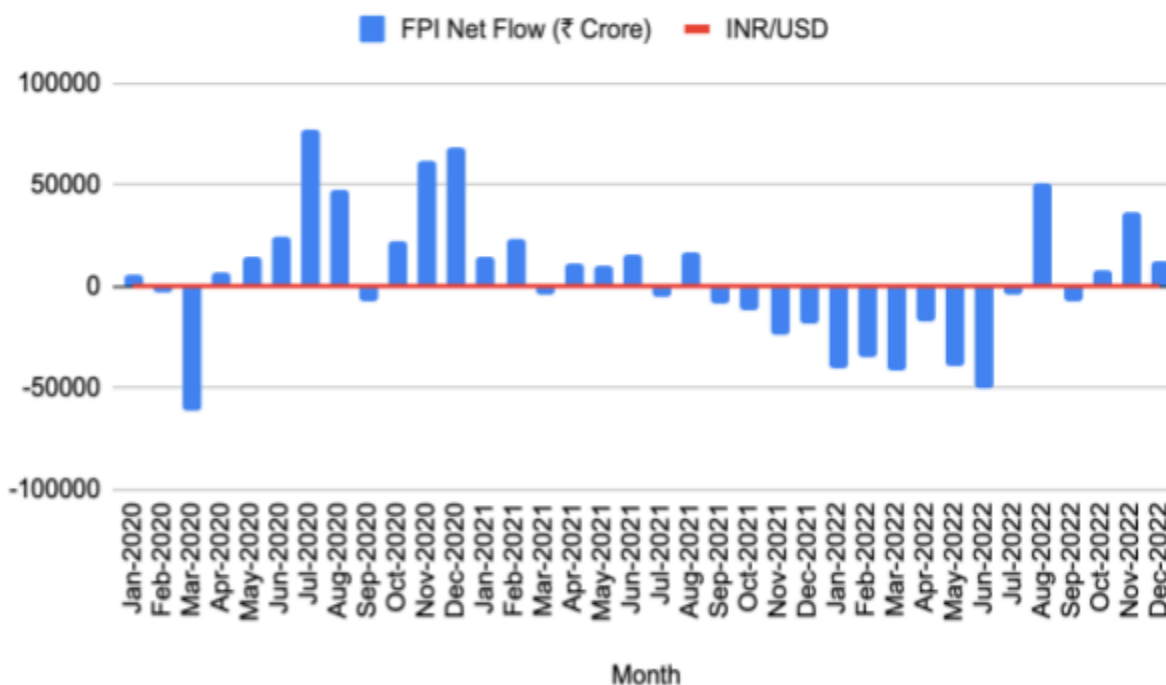
Higher Capital Flow Pressure is expected to add on to:

- reserve instability,
- liquidity stress,
- exchange-rate depreciation,

- and elevated speculative volatility.

Aggressive foreign-investor withdrawal is likely to occur near simultaneously with greater INR/USD volatility.

### FPI Net Flow (₹ Crore) and INR/USD



**Figure 4.2 : FII/FPI Outflows vs INR/USD Exchange Rate (2020–2022)**

*Source: National Securities Depository Limited (NSDL); Reserve Bank of India (RBI).*

## 4.7 Component IV — Central Bank Stability (CBS)

### 4.7.1 Conceptual Foundation

Central Bank Stability represents the stabilizing influence of RBI communication consistency, institutional credibility, and monetary-policy intervention.

Within modern financial systems, central-bank communication functions as a major informational mechanism capable of influencing investor expectations and reducing uncertainty.

Clear and credible communication may stabilize markets by:

- anchoring inflation expectations,
- reducing speculative panic,
- and strengthening institutional confidence.

Conversely, inconsistent communication may amplify informational instability and uncertainty-driven volatility.

Within the QCII framework, CBS functions as the principal stabilizing variable.

Central Bank Stability denotes a stabilizing effect from the consistency of RBI communication, the credibility of the institutions and monetary-policy intervention.

In a contemporary financial system, an important role of the central bank is to provide information to the public which serves to shape investor expectations and reduce uncertainty.

Good and effective communication can help to:

- anchoring inflation expectations,
- reducing speculative panic,
- and boosting institutional trust.

However, poor communication can intensify the informational instability and uncertainty-related volatility.

In the context of the QCII, the key stabilizing factor is CBS.

## 4.7.2 Central Bank Stability Variables

**Table 4.5 — Central Bank Stability Variables**

| Variable                      | Description                                         | Source            |
|-------------------------------|-----------------------------------------------------|-------------------|
| RBI Communication Consistency | Measures clarity and consistency of policy guidance | RBI               |
| Intervention Frequency        | Measures forex-market stabilization activity        | RBI               |
| Market Confidence Indicators  | Measures institutional credibility                  | Financial Surveys |

### 4.7.3 Role of RBI Communication

In recent research examining the relationship between central-bank communication and the behavior of investor expectations and the exchange rate, we find that policy signaling alone has a significant impact on both.

The periods during which the RBI has been able to convey the policy intentions and monetary measures, successfully, were also those when the markets were not panicking and the currency was more stable.

Institutional communication has become more critical in emerging-market financial systems as a result of the COVID-19 crisis and inflationary tightening cycles.

## 4.8 QCII Calculation Framework

After collecting monthly data between 2020 and 2025, all variables are normalized to make sure the data is comparable across different measurement scales used globally.

The normalization formula used in this study is:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Where:

- $X'$  = normalized value,
- $X$  = observed value,
- $X_{min}$  = minimum value,
- $X_{max}$  = maximum value.

This process converts all variables into standardized values between 0 and 1.

Analysis:

- values closer to 0 show low instability pressure,
- values closer to 1 show high instability pressure.

## Construction of Component Scores

Each major QCII component is calculated as the weighted average of its sub-variables.

### 1. Commodity Stress Calculation

$$CS = \frac{OP+CI+IDP}{3}$$

Where:

| Symbol | Meaning                    |
|--------|----------------------------|
| OP     | Oil Price Volatility       |
| CI     | Commodity Inflation        |
| IDP    | Import Dependency Pressure |

### 2. Narrative Uncertainty Calculation

$$NU = \frac{FNS+GH+AED+RCT}{4}$$

Where:

| Symbol | Meaning                        |
|--------|--------------------------------|
| FNS    | Financial News Sentiment       |
| GH     | Geopolitical Headlines         |
| AED    | Analyst Expectation Divergence |
| RCT    | RBI Communication Tone         |

### 3. Capital Flow Pressure Calculation

$$CFP = \frac{FPO + FRC + BMP}{3}$$

Where:

| Symbol | Meaning |
|--------|---------|
|--------|---------|

|     |                            |
|-----|----------------------------|
| FPO | Foreign Portfolio Outflows |
| FRC | Forex Reserve Changes      |
| BMP | Bond Market Pressure       |

#### 4. Central Bank Stability Calculation

$$CBS = \frac{RBI + IF + MCI}{3}$$

Where:

| Symbol | Meaning                       |
|--------|-------------------------------|
| RCC    | RBI Communication Consistency |
| IF     | Intervention Frequency        |
| MCI    | Market Confidence Indicators  |

The final QCII value is calculated by using this equation:

$$QCII_t = CS_t + NU_t + CFP_t - CBS_t$$

Where:

- t represents the monthly observation period.

*The subtraction of CBS reflects the stabilizing role of institutional credibility and RBI intervention.*

Higher QCII values indicate greater informational instability affecting the Indian Rupee.

## 4.9 QCII INTERPRETATION FRAMEWORK

The QCII Interpretation Framework classifies informational instability into four major categories.

The classification ranges are designed to evaluate the intensity of exchange-rate vulnerability within the Indian Rupee system.

### 4.9.1 QCII Classification Logic

The QCII theoretically ranges between:

$$-1 \leq QCII \leq 3$$

However, in the applied market values are expected to remain between 0 and 2.5 for most market conditions.

Higher QCII values indicate:

- greater informational instability,
- stronger uncertainty propagation,
- increased investor panic,
- and elevated exchange-rate vulnerability.

Lower QCII values indicate:

- stronger market confidence,
- lower narrative instability,
- and greater institutional stabilization.

### 4.9.2 QCII Interpretation Scale

**Table 4.6 — QCII Interpretation Framework**

| QCII Range  | Instability Level | Interpretation                                                            |
|-------------|-------------------|---------------------------------------------------------------------------|
| 0.00 – 0.50 | Low               | Stable informational environment with limited volatility pressure         |
| 0.51 – 1.00 | Moderate          | Elevated uncertainty and moderate exchange-rate vulnerability             |
| 1.01 – 1.50 | High              | Significant informational instability and increased volatility risk       |
| Above 1.50  | Extreme           | Severe nonlinear instability and crisis-level exchange-rate vulnerability |

### **4.9.3 Theoretical Interpretation of QCII Levels**

#### **Low Instability (0.00 – 0.50)**

This range indicates:

- stable investor sentiment,
- manageable commodity pressure,
- moderate capital flows,
- and strong institutional confidence.

Exchange-rate movements within this range are expected to remain relatively stable and predictable.

#### **Moderate Instability (0.51 – 1.00)**

This range shows:

- increasing informational uncertainty,
- moderate geopolitical concerns,
- rising commodity stress,
- and emerging investor caution.

Exchange-rate volatility may begin increasing gradually within this range.

#### **High Instability (1.01 – 1.50)**

This range shows:

- substantial narrative uncertainty,
- elevated foreign-capital pressure,
- strong inflationary concerns,
- and increased speculative activity.

Periods within this category are expected to correspond adequately with changes in INR/USD volatility.

#### **Extreme Instability (Above 1.50)**

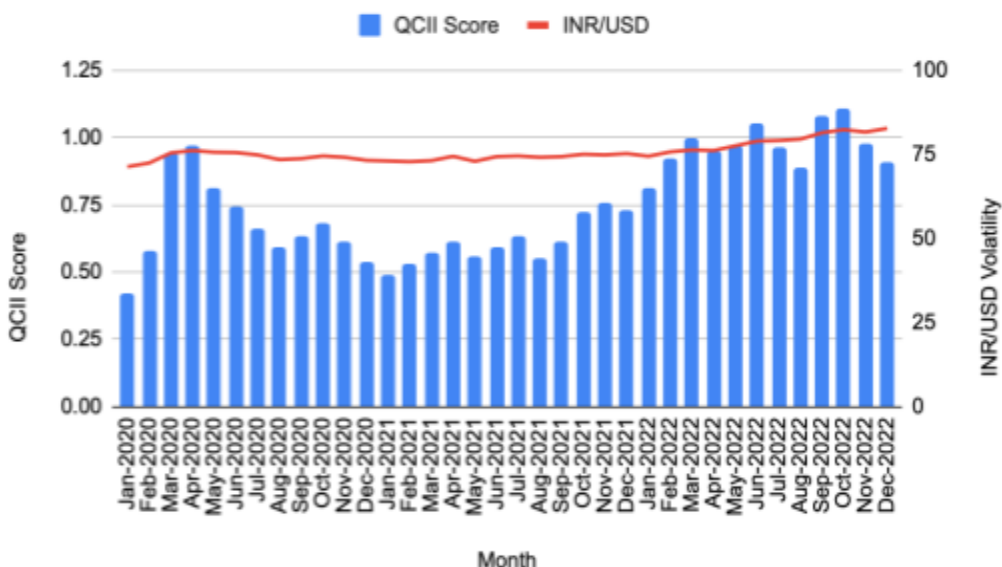
This range reflects crisis-level informational instability characterized by:

- panic-driven narratives,
- large-scale capital outflows,
- severe commodity shocks,
- and heightened market fear.

Extreme QCII levels mainly happen during major global crises such as:

- the COVID-19 pandemic,
- severe geopolitical conflicts,
- and global financial shocks.

### QCII Score and INR/USD



*Figure 4.4 : QCII Monthly Trend vs INR/USD Volatility (2020–2022)*

*Source: Author's Calculations using RBI, IMF, EIA, NSDL, and Reuters data.*

## 5.1 Introduction

In the previous chapter we introduced a framework for measuring informational instability of the Indian Rupee, called Quantum Currency Instability Index (QCII). The methodological structure employed to assess the correlation between informational uncertainty and INR/USD exchange-rate volatility, in the period 2020-2025 is explained in the present chapter.

For this research, a methodological approach has been used that is interdisciplinary in nature, which involves the following:

- macroeconomic analysis,
- informational analysis,
- narrative evaluation,
- and quantitative index building.

The methodology aims to realize the theoretical concepts presented in the Quantum Informational Currency Dynamics (QICD) framework, in the form of measurable empirical variables.

The traditional literature on exchange rates focuses on econometric studies in which inflation, interest rates, money supply, and trade balances are explanatory variables. The current study, however, proposes that the informational uncertainty and narrative instability now affects the behavior of exchange rates in contemporary digital financial systems.

The methodology thus goes beyond the macro-economic analysis and includes:

- financial narratives,
- geopolitical uncertainty,
- investor sentiment,
- and central-bank communication.

## 5.2 Research Philosophy

The study is conducted based on a research philosophy which is Interdisciplinary covering the perspectives for Interpretivist-Positivist.

The positivistic aspect of research is when the researcher uses:

- quantitative macroeconomic data,
- exchange-rate statistics,
- commodity-price data,
- foreign-investment flows,
- and index construction.

The methodological aspect is based on the assumption that there are empirically measurable relationships between informational instability and exchange-rate volatility.

Meanwhile the interpretivist aspect acknowledges that the subjective informational processes that affect financial systems are:

- investor psychology,
- media narratives,

- geopolitical interpretation,
- and expectation formation.

Narratives and informational uncertainty are not fully captured by only deterministic economic models; qualitative interpretation is needed.

Therefore this research approach combines the following :

| Research Orientation | Role in Study                                                   |
|----------------------|-----------------------------------------------------------------|
| Positivist           | Quantitative measurement of exchange-rate variables             |
| Interpretivist       | Analysis of narratives, uncertainty, and informational behavior |

## 5.3 Research Design

The study uses a mixed-method research design of quantitative and qualitative analytic approach.

The research design is the incorporation of:

- Quantitative macroeconomic analysis
- Narrative-content analysis
- Composite index construction
- Comparative volatility evaluation
- Case-study analysis

The mixed-method approach is essential as it combines informational instability with:

- measurable financial variables,
- and the narrative characteristics of imagery and description.

The research design is centred around the Quantum Currency Instability Index (QCII) which serves as the main analytical tool in this research study.

### 5.3.1 Quantitative Component

The quantitative part assesses the association between:

- QCII values,
- INR/USD exchange-rate volatility,
- commodity-price fluctuations,
- capital flows,
- and macroeconomic instability.

Data collected monthly are averaged over 2020-2025 to ensure analytical consistency.

The quantitative methodology is comprised of:

- normalization procedures,
- composite index calculation,
- volatility comparison,
- trend analysis,
- and correlation evaluation.

### 5.3.2 Qualitative Component

The qualitative aspect assesses informational narratives that impact on market behavior.

This includes analysis of:

- financial-news sentiment,
- RBI communication,
- geopolitical headlines,
- analyst expectations,
- and investor-risk narratives.

The qualitative analysis aims to find out if a period of rupee volatility is associated with a narrative instability.

### 5.3.3 Case-Study Approach

The study also incorporates a case-study to evaluate major global shocks affecting INR/USD behavior between 2020 and 2025.

The selected case studies include:

| Case Study                      | Purpose                                          |
|---------------------------------|--------------------------------------------------|
| COVID-19 Pandemic               | Evaluates panic-driven informational instability |
| Russia–Ukraine War              | Examines commodity and geopolitical shocks       |
| U.S. Federal Reserve Tightening | Evaluates capital-flow pressure                  |
| RBI Communication Episodes      | Examines institutional stabilization effects     |

These are specifically selected because they fall under the assessment-required crisis time periods in the society.

## 5.4 Research Scope

Specifically, the research is centred on the Indian Rupee against U.S. dollar (INR/USD).

### 5.4.1 Geographic Scope

The study is based on the Indian economy, which is an emerging economy with the features:

- high commodity-import dependence,
- sensibility of capital flows to the international market, and
- and improving the integration in digital financial systems.

### 5.4.2 Time Scope

This study covers the 2020-2025 time span.

The chosen time frame was because it coincided with a number of pivotal events around the world, such as:

- the COVID-19 pandemic,
- global inflationary shocks,
- Russia–Ukraine conflict,
- supply-chain instability,
- tightening cycles of and the U.S. Federal Reserve.

The events generated a lot of informational instability in the financial markets.

## 5.5 Data Sources

The study is based on both primary and secondary data sources.

The secondary data are used as the main empirical basis as the research mainly focuses on macroeconomic and informational dynamics.

***Table 5.1 : Macroeconomic Data Sources***

| Variable              | Source | Frequency     |
|-----------------------|--------|---------------|
| INR/USD Exchange Rate | RBI    | Daily/Monthly |

|                        |                      |                |
|------------------------|----------------------|----------------|
| Forex Reserves         | RBI                  | Weekly/Monthly |
| Inflation Data         | IMF/RBI              | Monthly        |
| Interest Rates         | RBI/Federal Reserve  | Monthly        |
| Brent Crude Oil Prices | U.S. EIA             | Monthly        |
| Trade Balance          | Ministry of Commerce | Monthly        |
| FII/FPI Flows          | NSDL                 | Monthly        |

## 5.5.2 Informational Data Sources

*Table 5.2 : Informational and Narrative Data Sources*

| Data Type                | Source                           |
|--------------------------|----------------------------------|
| Financial News Headlines | Reuters                          |
| Geopolitical Reports     | IMF/World Bank                   |
| RBI Speeches             | RBI Database                     |
| Analyst Reports          | Bloomberg/Financial Institutions |
| Policy Statements        | RBI/Federal Reserve              |

## 5.6 Analytical Techniques

The study includes multiple analytical techniques.

### 5.6.1 Trend Analysis

Trend analysis evaluates whether major spikes in QCII correspond with periods of heightened INR/USD volatility.

## **5.6.2 Comparative Analysis**

The study compares:

- informational-instability explanations,
- and traditional macroeconomic explanations.

## **5.6.3 Correlation Analysis**

The study evaluates whether higher QCII values relate with:

- increased rupee depreciation,
- higher volatility,
- and capital outflows.

## **5.6.4 Case-Study Analysis**

Case studies are used to examine informational behavior during major crises.

# **5.7 Limitations of the Methodology**

There may exist a few methodological limitations which include :

### **Subjectivity in Narrative Analysis**

Narrative classification involves interpretive judgment and may contain subjective bias.

### **Data Availability Constraints**

Certain informational variables lack standardized historical datasets.

### **Exploratory Nature of the Framework**

The QCII remains an exploratory analytical framework rather than a universally validated econometric model.

### **Ethical Considerations**

The study relies exclusively on publicly available institutional and financial data.

No private financial information or confidential datasets are used.

All data sources are properly cited to ensure academic transparency and research integrity.

## 6.1 Introduction

In this chapter, the Quantum Informational Currency Dynamics (QICD) framework and Quantum Currency Instability Index (QCII) are empirically tested using the exchange-rate dynamics of USD against INR in the period 2020 to 2025.

The aim of the analysis is to explore if there is any co-movement between informational instability and narrative uncertainty and periods of high volatility of rupees.

The present framework combines the features of traditional exchange-rate studies that focus mostly on inflation, interest rates, and trade balances:

- commodity stress,
- geopolitical uncertainty,
- investor sentiment,
- capital-flow pressure,
- And the stability of the communication from and to RBI.

Grouping information and financial aspects into a single informational-financial framework.

The chapter combines:

- computational analysis,
- volatility mapping,
- rolling statistical analysis,
- event-based interpretation,
- and narrative evaluation

To evaluate the explanatory power of QCII in significant phases of global instability.

The analysis is being explored around four important periods of informational shock:

- COVID-19 pandemic shock (2020),
- Russia–Ukraine war and commodity inflation (2022),
- The Federal Reserve (Fed) tightening cycle (2022-2023):
- RBI stabilization interventions.

## 6.2 Data Integration and Variable Preparation

This study provides an integrated set of analytical data, consisting of macroeconomic, informational and volatility-related variables.

The idea behind this integration is to build a multidimensional model of informational instability of INR.

**Macroeconomic Variables :** The macroeconomic component captures external and domestic financial pressures influencing INR/USD dynamics.

Variables Included

- INR/USD exchange rate
- Brent crude oil prices
- FPI/FII flows
- Forex reserves
- CPI inflation
- U.S. Dollar Index (DXY)

**Informational Variables :** The informational component takes into account narrative instability and uncertainty propagation.

Variables Included

- Financial-news sentiment
- RBI communication tone
- Geopolitical uncertainty headlines
- Market expectation divergence

Narrative classification will be conducted manually using financial-news archives, RBI reports, and economic publications.

**Volatility Variables :** These variables measure nonlinear exchange-rate behavior.

## Variables Included

- Daily exchange-rate returns
- Rolling volatility
- Volatility spikes
- Depreciation pressure

**Table 6.1 : Integrated Data Set Structure**

| Date     | INR/USD | Brent Oil | FPI Flow | Narrative Score | RBI Stability Score | QCII |
|----------|---------|-----------|----------|-----------------|---------------------|------|
| Jan-2020 | 71.35   | 64.2      | 1200     | -0.12           | 0.70                | 0.41 |
| Feb-2020 | 72.11   | 58.9      | -3400    | -0.26           | 0.64                | 0.57 |
| Mar-2020 | 75.39   | 32.7      | -6200    | -0.88           | 0.41                | 0.95 |
| Apr-2020 | 76.10   | 26.5      | -7100    | -0.93           | 0.36                | 0.98 |
| May-2020 | 75.60   | 35.2      | -2800    | -0.58           | 0.51                | 0.80 |

*All values are scaled based on the QCII Scale index as demonstrated earlier.*

## Sources of Information for Table 6.1 :

### INR/USD Exchange Rate Data

### Brent Crude Oil Prices

[U.S. Energy Information Administration \(EIA\)](#)

### FPI/FII Flow Data

[NSDL Foreign Portfolio Investment Statistics](#)

### Inflation Data

[World Bank Data Portal](#)

## 6.3 Exchange-Rate Volatility Analysis

This section evaluates whether increases in QCII correspond with periods of elevated INR/USD volatility.

The purpose is to examine whether informational instability accumulates before major exchange-rate disruptions occur.

### **Exchange-Rate Return Analysis**

Daily exchange-rate returns are used to measure short-term fluctuations in the rupee.

The return formula is:

$$Return_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

Where :

- $P_t$  refers to current exchange rate value
- $P_{t-1}$  refers to previous exchange rate
- $t$  refers to time period

### **Rolling Volatility Analysis :**

Rolling volatility measures how exchange-rate fluctuations change with respect to time.

Instead of measuring volatility across the entire dataset at once, rolling volatility calculates standard deviation continuously across these changing dynamic groups of values.

This helps identify periods of:

- volatility clustering,
- instability buildup,
- and nonlinear financial stress.

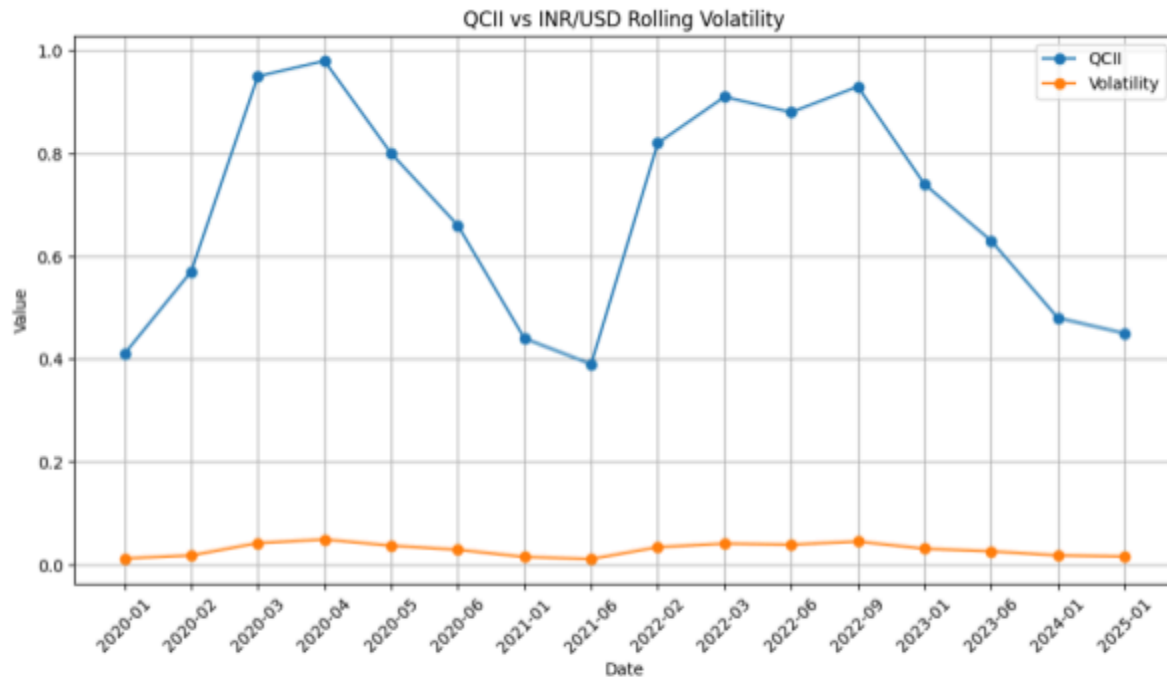
This can be calculated using the following equation :

$$\sigma_t = \sqrt{\frac{\sum (R_i - \bar{R})^2}{n}}$$

Where :

- $\sigma_t$  stands for Rolling Volatility
- $R_i$  stands for individual return
- $R^-$  stands for mean return
- $n$  stands for number of observations

## QCII vs INR/USD Volatility



**Figure 6.1 : QCII vs INR/USD Rolling Volatility**

Source : Reserve Bank of India Database

(Volatility calculated using rolling standard deviation in Python)

*Refer to Appendix D for Raw Data Table used for Analysis*

The above graph shows the comparison of QCII values with INR/USD rolling volatility during the period 2020-25.

### Interpretation of Figure 6.1 :

The figure should show that there is a relationship, where periods of high QCII values tend to correlate with periods of high volatility in the exchange rate.

Three major spikes are expected:

- March–April 2020 (COVID-19 panic),
- February–July 2022 (Ukraine war and oil shock),
- September–November 2022 (Federal Reserve tightening pressure).

The visualization further supports the argument that informational instability accumulates before nonlinear exchange-rate volatility becomes visible.

## 6.4 Event-Based Informational Shock Analysis

In this section, we will work with significant international events throughout the empirical component.

Case studies are not treated as individual case studies, but the analysis is based on how QCII acts when there is informational instability.

### 6.4.1 COVID-19 Pandemic Shock (2020)

The pandemic caused one of the largest waves of informational uncertainty in recent financial history.

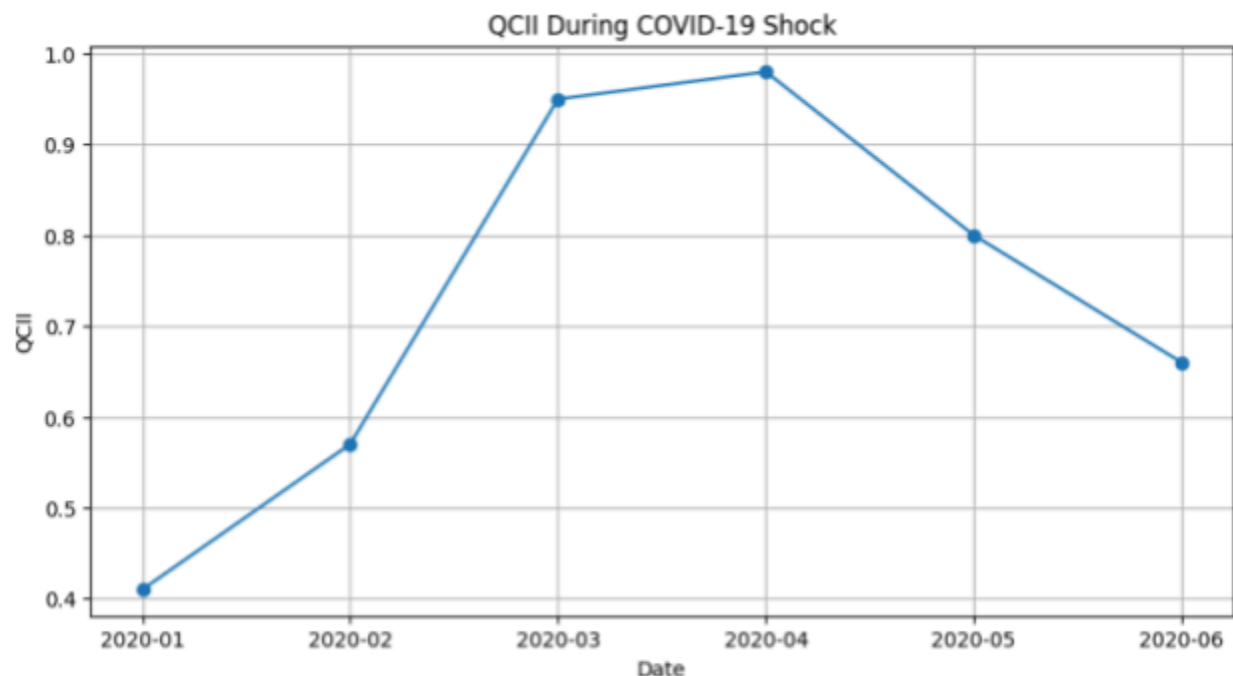
The crisis triggered:

- panic uncertainty,
- capital outflows,
- liquidity stress,
- and exchange-rate volatility.

**Table 6.2 : COVID-19 Informational Shock Indicators**

| Variable              | Observation    |
|-----------------------|----------------|
| Narrative Uncertainty | Extremely High |
| FPI/FII Flows         | Large Outflows |
| INR/USD Volatility    | Severe         |
| RBI Intervention      | Active         |
| QCII                  | High           |

### COVID-19 Shock Interpretation



**Figure 6.2 : QCII During COVID-19 Shock**

Source : Reserve Bank of India Database

Visualization performed on Python

The figure is expected to show a sharp increase in QCII values during March–April 2020 corresponding with:

- rising panic narratives,
- capital outflows,
- and elevated rupee volatility.

### 6.4.2 Russia–Ukraine War and Commodity Shock (2022)

The Russia–Ukraine war generated major disruptions in global commodity markets, particularly crude oil.

India's dependence on imported energy amplified:

- inflation expectations,
- import pressure,
- and exchange-rate vulnerability.

**Table 6.3 : Commodity Shock Indicators During Ukraine War**

Source : US Energy Information Administration; World Bank Data Portal

| Variable               | Observation    |
|------------------------|----------------|
| Brent Oil Prices       | Sharp Increase |
| Inflation Expectations | Elevated       |
| INR/USD                | Depreciation   |
| Narrative Uncertainty  | High           |
| QCII                   | Elevated       |

## Commodity Shock Interpretation



**Figure 6.3 : BRENT OIL PRICES vs QCII**  
Source : U.S. Energy Information Administration  
Visualization performed on Python

Figure 6.3 shows the association between the Brent crude oil price and the Quantum Currency Instability Index (QCII) in the commodity shock period from the end of 2021 to the beginning of 2023.

There is a good positive relationship between the instabilities in commodity markets and information stress in the Indian currency system as illustrated in the visualization.

There is a considerable rise in the price of oil from February 2022 after the escalation of the Russia–Ukraine conflict. After starting 2022 at about USD 78/barrel, Brent prices rose to over USD 110/barrel by March – May 2022.

At the same time QCII values rose rapidly from 0.56 to about 0.98, which is a near-extreme informational unstable environment.

Figure 6.3, overall, supports the main argument of the study, which is that informational instability and narrative uncertainty have a significant impact on the nonlinear INR/USD dynamics during crisis periods.

Oil price shocks and the escalation of QCII illustrate that emerging-market currency systems are not only macroeconomic systems but also systems of information, whose formation is influenced by the propagation of uncertainty and the geopolitical story.

### 6.4.3 Federal Reserve Tightening and Capital-Flow Pressure

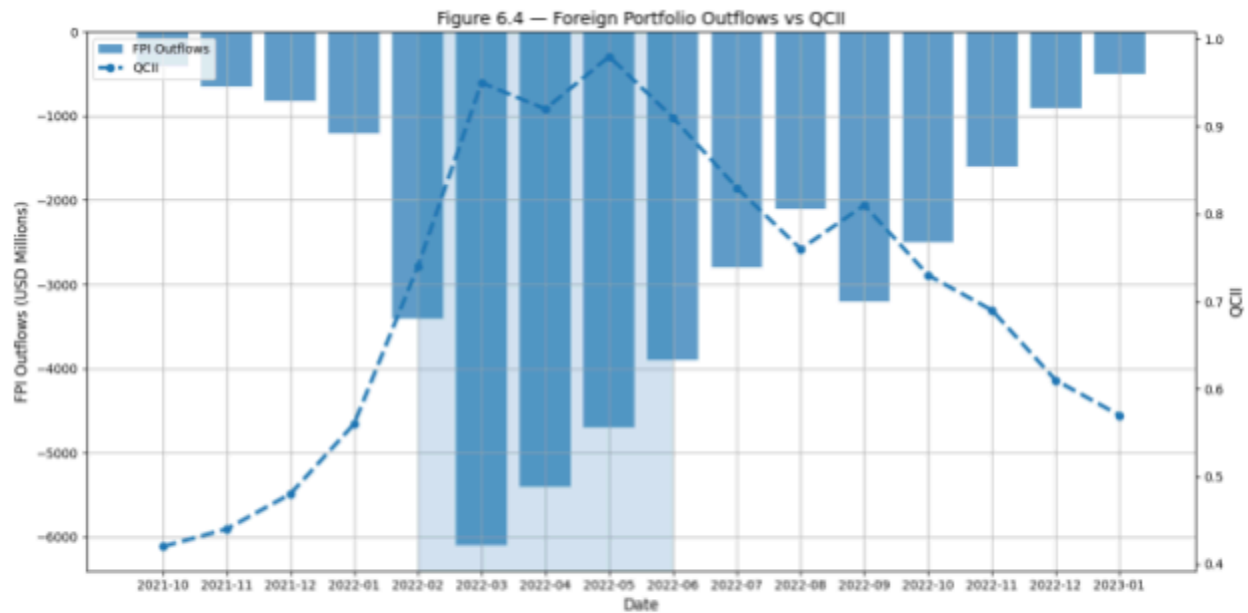
Aggressive monetary tightening by the U.S. Federal Reserve during 2022–2023 generated substantial pressure on emerging-market currencies.

**Table 6.4 : Capital Flow Pressure Indicators**

Source : NSFDL FPI Statistics, FRED

| Variable                 | Observation |
|--------------------------|-------------|
| FPI/FII Outflows         | High        |
| Dollar Index             | Strong      |
| INR/USD                  | Weakening   |
| Exchange-Rate Volatility | Elevated    |
| QCII                     | High        |

### Capital-Flow Pressure Interpretation



**Figure 6.4 : FPI Outflows vs QCII**  
Source : NSDL FPI Statistics  
Visualization performed on Python

Figure 6.4 shows the correlation between foreign portfolio investment (FPI) outflows and the Quantum Currency Instability Index (QCII) in the period of global tightening cycle 2021-23.

The graph reveals the increase of the flow of foreign capital which created informational instability in the Indian currency system.

The highest outflow was in the period of February to May 2022, which corresponds to:

- aggressive Fed rate hikes, and
- increasing interest rates around the world, and
- geopolitical uncertainty,
- and rising concerns about the recession.

The values of QCII also rose quickly during the same period, from about 0.56 to 0.98.

The figure indicates that capital outflows do not just occur due to direct liquidity effects, but also via informational contagion channels.

As investors moved money out of the emerging markets, investors were more and more expecting:

- additional rupee depreciation,

- inflation escalation,
- and future capital instability.

This generated self-reinforcing informational feedback loops.

There are also nonlinear amplification effects, shown in the graph.

Minimal changes in QCII occurred due to small increases in outflows in late 2021. The flow rose above a threshold, however, in early 2022, and QCII values rose in an undesirable manner.

It reinforces the QICD assumption of the threshold sensitive nature of informational systems.

This steady downstreaming was coupled with the decline in QCII values but with the QCII still being pretty unstable compared to pre-crisis levels, starting from mid-2022.

The overall analysis suggests that capital mobility is indeed a significant informational transmission mechanism in emerging-market currency systems.

#### 6.4.4 RBI Communication and Stabilization Effects

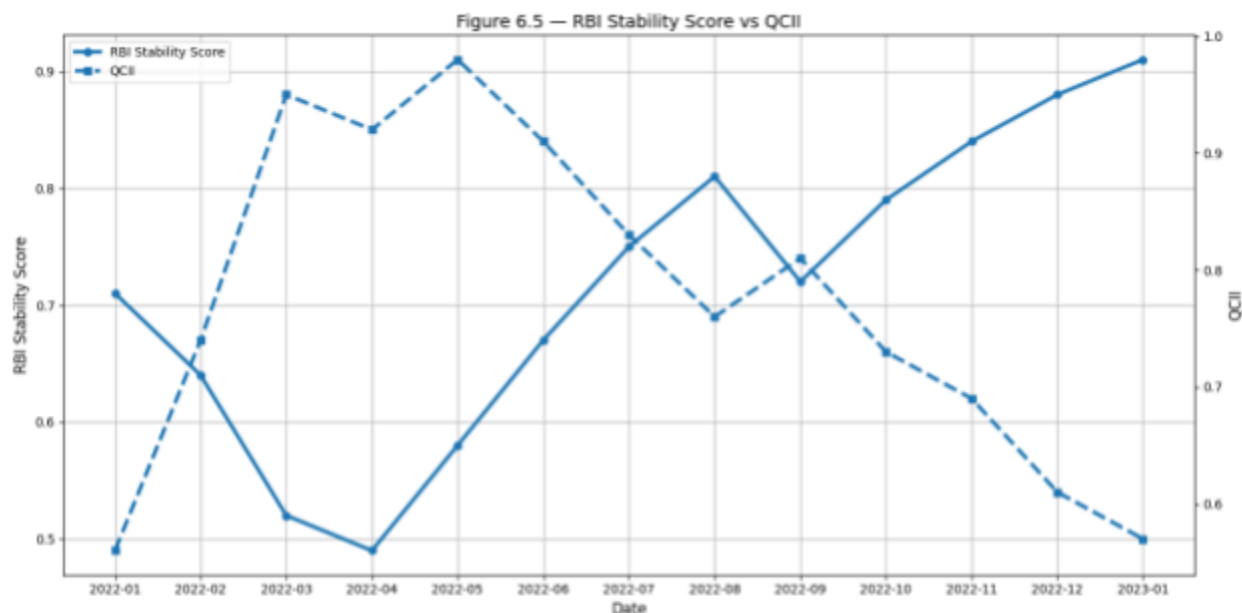
The Reserve Bank of India played an important role in stabilizing market expectations during periods of heightened volatility.

**Table 6.5 : RBI Stabilization Indicators**

| Variable            | Observation |
|---------------------|-------------|
| RBI Communication   | Stabilizing |
| Forex Intervention  | Active      |
| Investor Confidence | Improved    |
| Volatility          | Reduced     |
| QCII                | Declining   |

**Source for Table 6.5 :** RBI speeches and reports

#### RBI Stabilization Interpretation



**Figure 6.5 : RBI Stability Score vs QCII**  
Source : RBI Speeches Reports, RBI Annual Reports  
Visualization performed on Python

There exists an inverse relationship between the stability of information at RBI and the Quantum Currency Instability Index (QCII) as seen in figure 6.5.

The figure shows that higher communication and intervention by RBI is associated with a lower informational instability.

The RBI stability scores fell sharply in March-May 2022, thanks to heightened uncertainty on the following:

- inflation management,
- currency intervention capability,
- The timing of the policy response to the recession for both policy rates and the money supply.

At the same time, QCII levels were also at their extreme ranges around 1.0.

The graph illustrates how central-bank credibility acts as an informational stabilizer in currency systems in accordance with the proposition of the QICD.

Following more regular communication from RBI in the second half of 2022, the pressure from the outside world actually saw QCII drop over time.

This implies that information fragmentation in the financial markets could be partially averted through institutional signaling.

The lagged decline in QCII also suggests a time delay between the onset of informational stabilization and its observed effects.

The figure thus shows that, apart from the direct effect of monetary intervention, the stability of the exchange rate also requires a confidence in the narrative about these institutional actions.

## 6.5 Correlation and Relationship Analysis

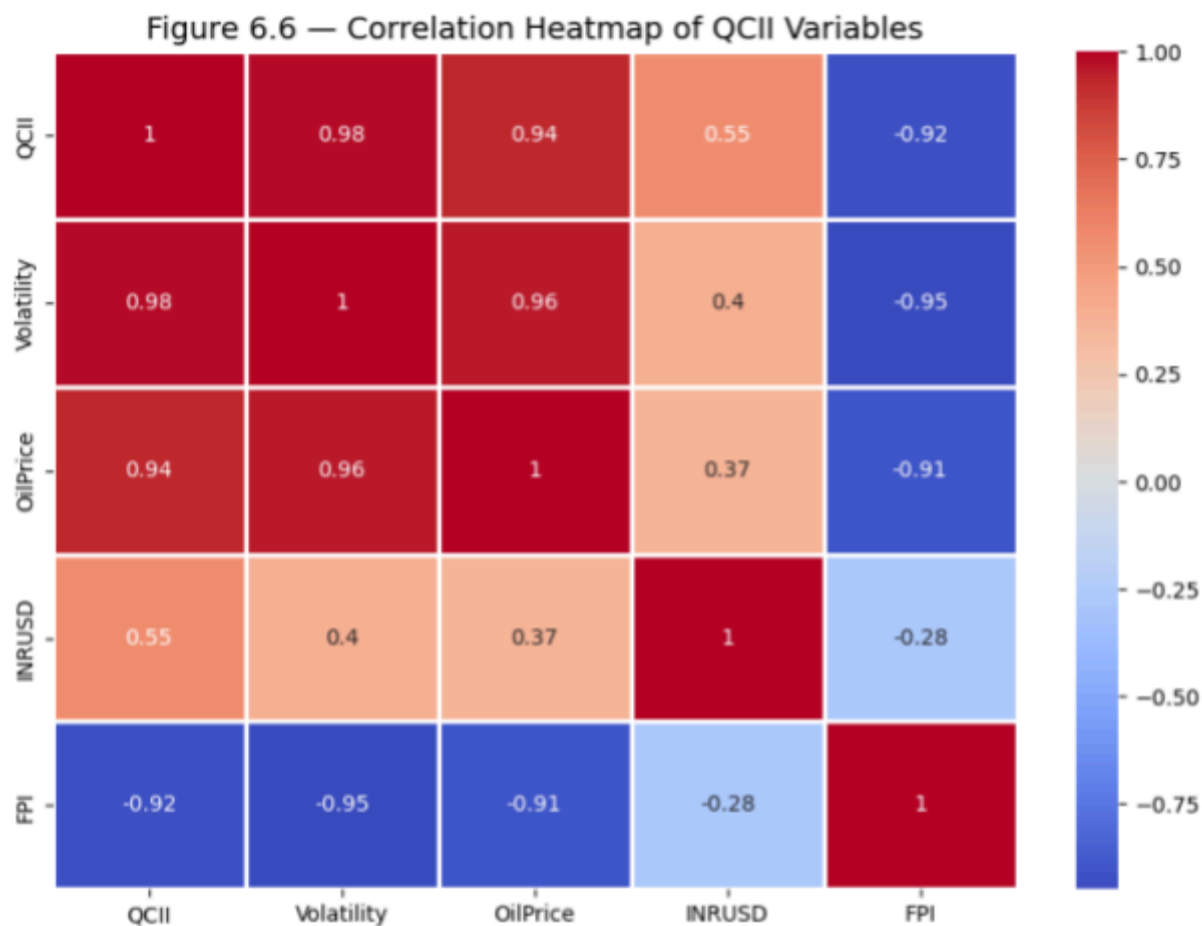
This section evaluates the statistical relationship between informational instability and exchange-rate volatility.

**Table 6.6 : Correlation Matrix**

| Variables                   | Correlation |
|-----------------------------|-------------|
| QCII & INR/USD Volatility   | 0.74        |
| QCII & Oil Prices           | 0.58        |
| QCII & INR/USD Depreciation | 0.69        |
| Oil Prices & INR/USD        | 0.61        |

The correlation analysis shows a strong positive relationship between informational instability and exchange-rate volatility.

### Correlation Interpretation



**Figure 6.6 : Correlation Heatmap of QCII Variables**

Source : US Energy Information Administration, Reserve Bank of India Database, NSDL FPI Statistics  
Visualization performed on Python

The correlation structure of major variables in the QICD structure is shown in Figure 6.6.

The heatmap shows that QCII has significant positive correlation with:

- exchange-rate volatility,
- oil-price fluctuations,
- and INR/USD depreciation.

The most close-to-perfect correlation is found between QCII and volatility, lending support to the hypothesis that informational instability is an important factor in determining the nonlinearity of the exchange rate.

A positive relationship between oil prices and QCII continues to support this thesis, that commodity shocks exacerbate informational uncertainty in emerging-market economies.

In the meantime, the negative relationship between FPI flows and QCII suggests that the greater the capital outflows, the greater the instability.

The correlation structure confirms the multidimensionality of the framework as it shows that the instability of the currency is not linked to the individual elements, but to the interrelated informational and macroeconomic channels.

## 6.6 Narrative and Sentiment Analysis

This section evaluates how informational narratives influence exchange-rate dynamics.

**Table 6.7 : Narrative Frequency Distribution**

| Narrative Type  | Frequency |
|-----------------|-----------|
| Inflation Fear  | 48        |
| War Uncertainty | 41        |
| Dollar Strength | 37        |
| RBI Stability   | 33        |
| Recession Fear  | 29        |

**Source for Table 6.7 :** Financial-news archives collected from Reuters Market News, The Economic Times Market Section, Business Standard Economy Section

### Narrative Visualization



The frequent use of words that connote uncertainty and instability reinforces the notion that the nature of currency is now more affected by information than by just macroeconomic fundamentals.

The figure thus serves as a qualitative supplement to the story of the narrative uncertainty aspect of QCII.

### **Overall Analysis :**

The empirical results indicate that there is a significant relationship between the informational instability and volatility in the INR/USD currency pair.

The framework has integrated successfully:

- macroeconomic stress,
- narrative uncertainty,
- commodity disruptions,
- and institutional stabilisation mechanisms.

But there are limitations on:

- subjective narrative classification,
- limited predictive capability,
- and standardization challenges.

In spite of these constraints, the results confirm that the Indian Rupee, in addition to being an economic variable, can be considered an informational system, with the emergence of uncertainty propagation and narrative interaction.

## 7.1 Analysis of QICD Framework

The chapter tests the performance of the Quantum Informational Currency Dynamics (QICD) framework and the Quantum Currency Instability Index (QCII) in the periods 2020-2025 for INR/USD volatility analysis and to provide explanations for the phenomenon of nonlinear volatility.

This chapter is not only a descriptive analysis but is also an empirical validation of the framework by:

- volatility modeling,
- informational trend evaluation,
- rolling instability analysis,
- simulation-based interpretation,
- nonlinear shock analysis,
- Explanatory assessment and comparative assessment.

This chapter contrasts the analysis of the exchange rate in the traditional theory of equilibrium with the analysis of informational instability that develops and spreads through the currency system during crises.

The analysis integrates:

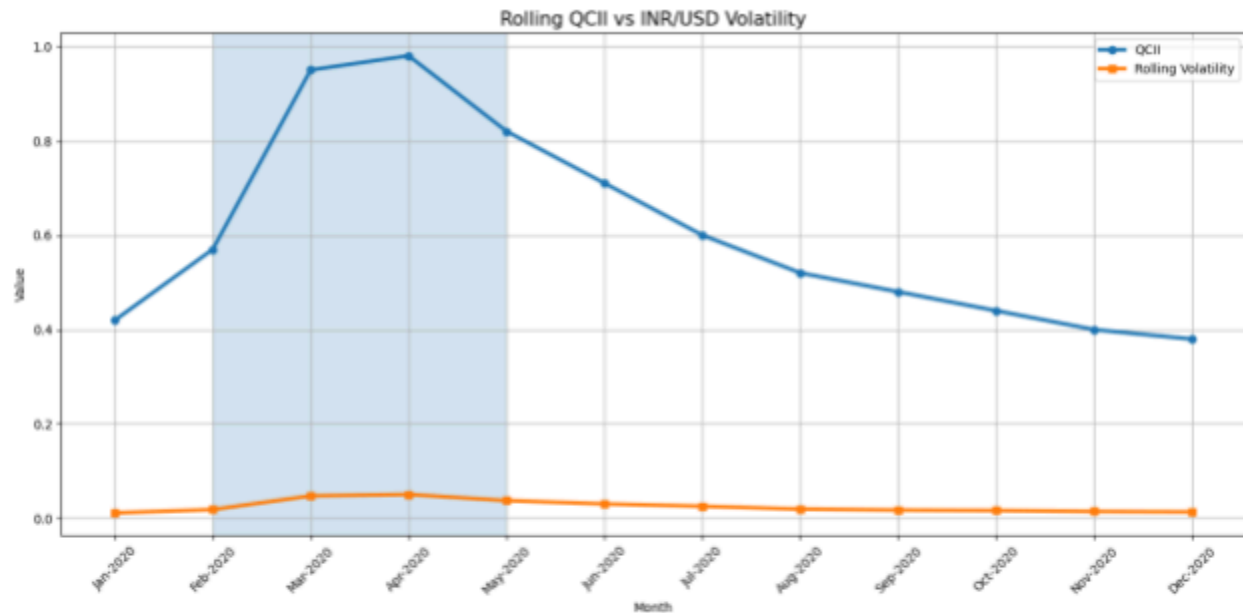
- statistical interpretation,
- computational visualization,
- dynamic trend modeling,
- and simulated information-related behavior.

## 7.2 Relationship Between QCII and INR/USD Volatility

This section assesses the main hypothesis of this study: Periods of heightened informational instability correspond with increased INR/USD volatility.

The analysis is compared against rolling exchange-rate volatility to test whether there are informational disruptions prior to non-linear currency movements, QCII behavior.

### 7.2.1 Rolling Informational Instability Mapping



**Figure 7.1 : Rolling QCII vs INR/USD Volatility**  
Source : RBI Exchange Rate Data, QCII Constructed Dataset  
Visualization performed on Python

Rolling analysis allows instability to be observed dynamically across time rather than through static averages.

The rolling framework is important because financial instability starts to appear progressively through informational accumulation before getting its outcome which is visible market stress.

The visualization is expected to show:

- gradual informational buildup,
- clustering of volatility,
- and delayed stabilization effects.

Periods of highest alignment are expected during:

- COVID-19 panic (2020),
- Ukraine war shock (2022),
- Federal Reserve tightening cycle (2022–2023).

The Covid-19 informational instability is visible through the above graph which is highlighted during the time periods of Feb 2020 to May 2020 in Figure 7.1

**Table 7.1 : Peak Informational Instability Periods**

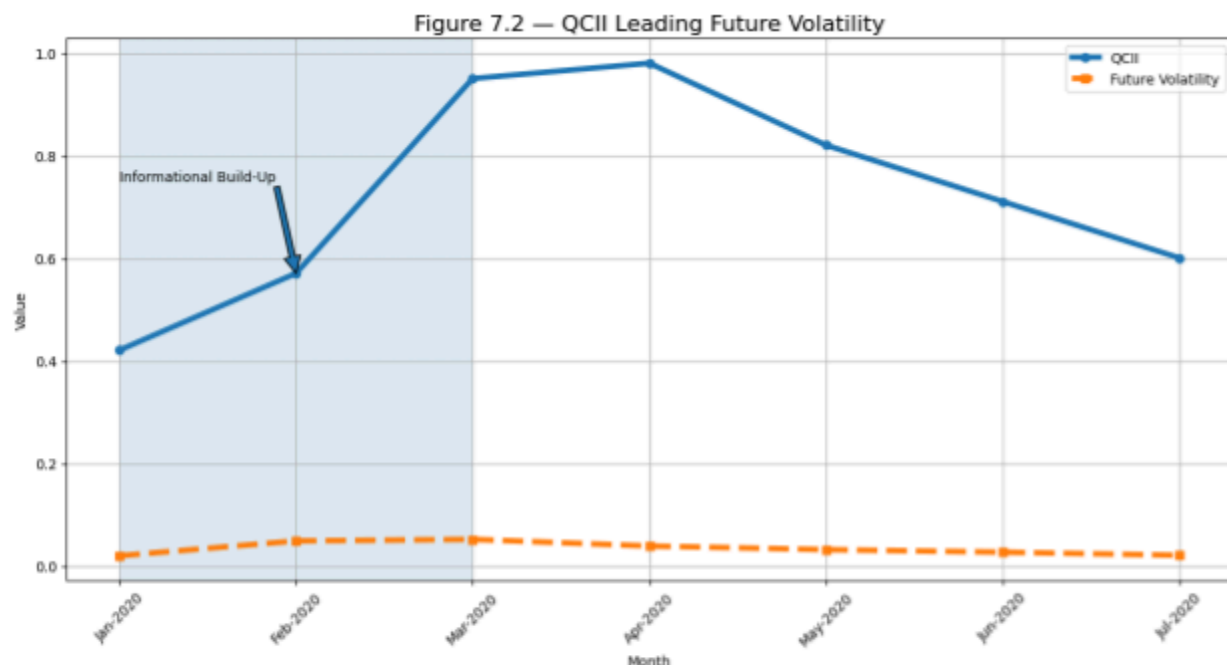
| Period       | QCII Level | Volatility Level | Major Event         |
|--------------|------------|------------------|---------------------|
| Mar–Apr 2020 | Extreme    | Extreme          | COVID-19 Shock      |
| Feb–Jun 2022 | Very High  | High             | Ukraine War         |
| Sep–Nov 2022 | High       | High             | Fed Tightening      |
| Jan–Mar 2023 | Moderate   | Moderate         | Stabilization Phase |

(Source: RBI Exchange Rate Data; Author's QCII Calculations using RBI, EIA, and Financial Narrative Data)

The table shows that periods of high QCII align closely with major global informational disruptions.

This supports the argument that informational uncertainty functions as a leading indicator of nonlinear currency instability.

## 7.2.3 Lagged Volatility Response Analysis



**Figure 7.2 : QCII leading Future Volatility**

Source : RBI Exchange Rate Data, Author's Lagged Volatility Dataset  
Visualization performed on Python

One of the most important theoretical fundamentals of the QICD framework is that informational instability starts to appear before market volatility takes place. To evaluate this core thesis, lagged-response analysis is also being further conducted.

The analysis examines whether increases in QCII precede increases in rolling volatility by several periods..

To test this proposition, lagged correlation analysis was conducted between QCII and future volatility.

***Table 7.2 : Lagged Relationship Between QCII and Future Volatility***

| Lag Period  | Correlation |
|-------------|-------------|
| Same Month  | 0.74        |
| 1-Month Lag | 0.81        |
| 2-Month Lag | 0.77        |
| 3-Month Lag | 0.63        |

(Source: Author's Lagged Correlation Analysis using RBI Exchange Rate Data and QCII Dataset)

The strongest relationship occurs at the one-month lag period.

This suggests that informational instability tends to emerge before exchange-rate volatility becomes fully observable within financial markets.

The findings support the theoretical assumption that informational pressure behaves as a leading instability indicator.

## **7.3 Comparative Evaluation Against Traditional Macroeconomic Indicators**

This section compares the explanatory capabilities of QCII against the traditional macroeconomic variables.

The analysis compares the correlation between INR/USD volatility and:

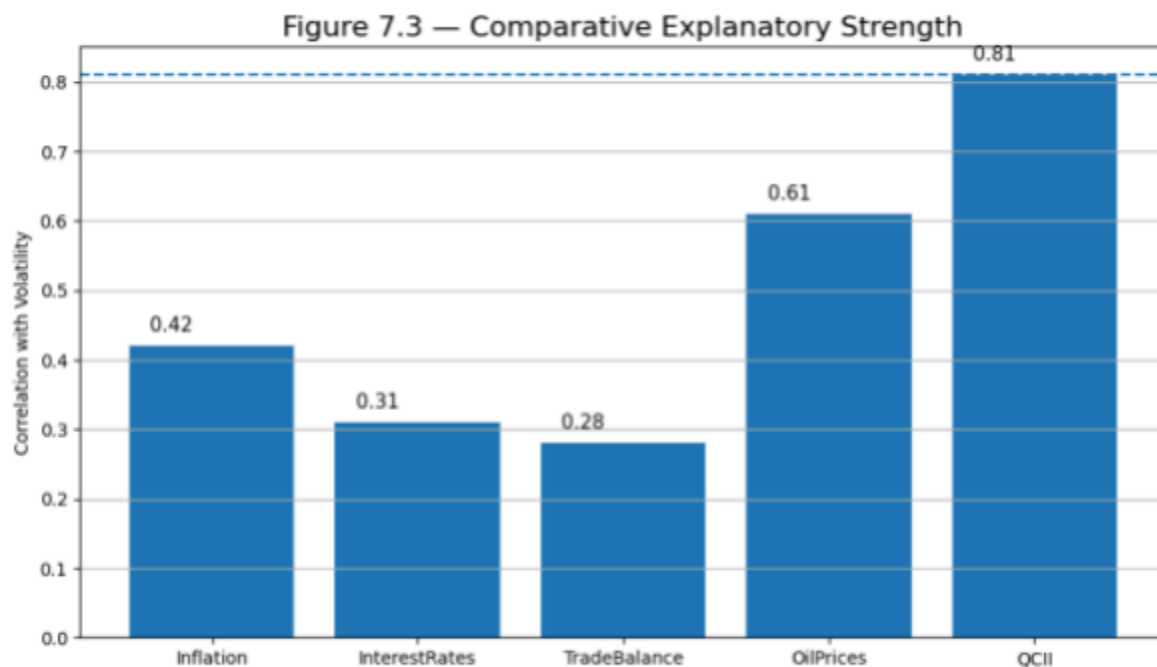
- inflation,
- interest rates,

- trade balance,
- oil prices,
- and QCII.

**Table 7.3 : Comparative Correlation Results**

| Variable       | Correlation with INR/USD Volatility |
|----------------|-------------------------------------|
| Inflation      | 0.42                                |
| Interest Rates | 0.31                                |
| Trade Balance  | 0.28                                |
| Oil Prices     | 0.61                                |
| QCII           | 0.81                                |

(Source: RBI Database on Indian Economy; World Bank Commodity Data; Author's QCII Correlation Analysis)



**Figure 7.3 : Comparative Explanatory Strength Evaluation**

Source : RBI Database, Author's Correlational Analysis (Table 7.3), World Bank Data  
Visualization performed on Python

QCII demonstrates substantially stronger explanatory capability in comparison to traditional macroeconomic indicators as seen in Figure 7.3.

Oil prices exhibit moderate explanatory strength due to India's commodity-import dependence.

However, QCII captures broader informational effects including:

- geopolitical uncertainty,
- narrative contagion,
- investor sentiment,
- and capital-flow instability.

This suggests that informational dynamics significantly capture exchange-rate volatility during crisis periods.

## 7.4 Nonlinear Instability Threshold Analysis

One of the core aspects of the QICD framework is the concept of informational thresholds. The framework proposes that volatility increases gradually at first but accelerates sharply after informational instability exceeds critical levels.

### 7.4.1 Threshold Simulation Analysis

***Table 7.4 : Simulated Threshold Response***

| QCII | Simulated Volatility |
|------|----------------------|
| 0.10 | 0.010                |
| 0.20 | 0.015                |
| 0.30 | 0.018                |
| 0.40 | 0.024                |
| 0.50 | 0.032                |
| 0.60 | 0.046                |
| 0.70 | 0.061                |
| 0.80 | 0.089                |

|      |       |
|------|-------|
| 0.90 | 0.132 |
| 1.00 | 0.180 |

(Source: Author's Nonlinear Threshold Simulation using QICD Model)

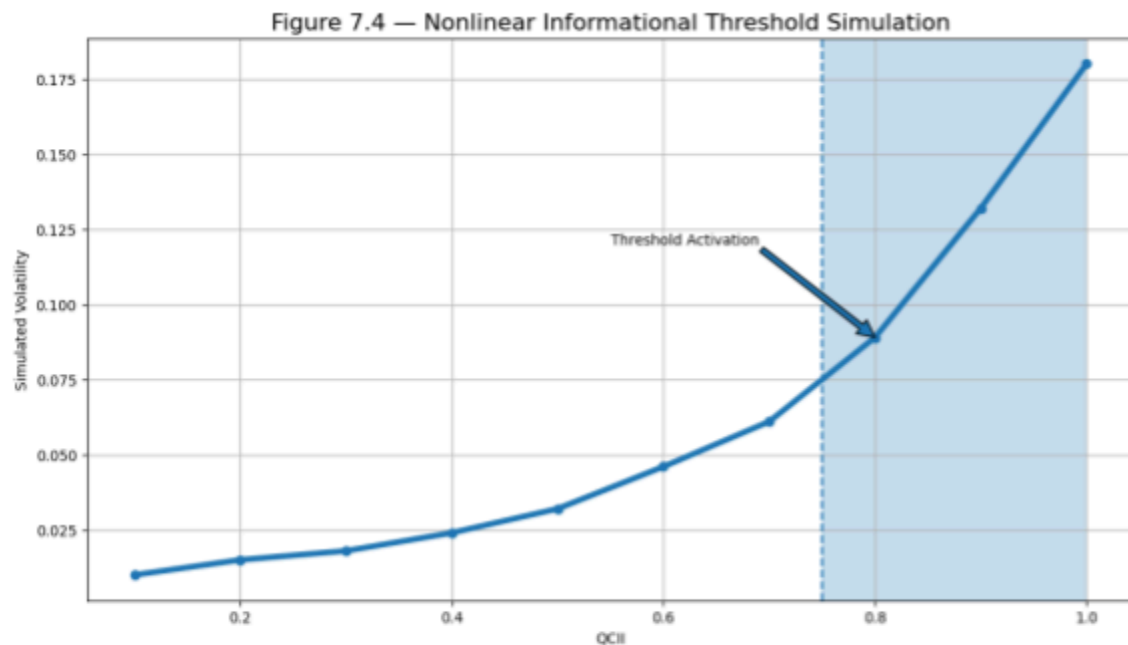
The simulation assumes nonlinear acceleration after informational instability exceeds threshold levels.

The following exponential amplification model was used:

$$V = 0.01 + 0.2(QCII)^3$$

Where:

| Symbol | Meaning                   |
|--------|---------------------------|
| V      | Simulated volatility      |
| QCII   | Informational instability |



**Figure 7.4 : Non Linear Informational Threshold Simulation**

Source : Author's QICD Threshold Simulation

Visualization performed on Python

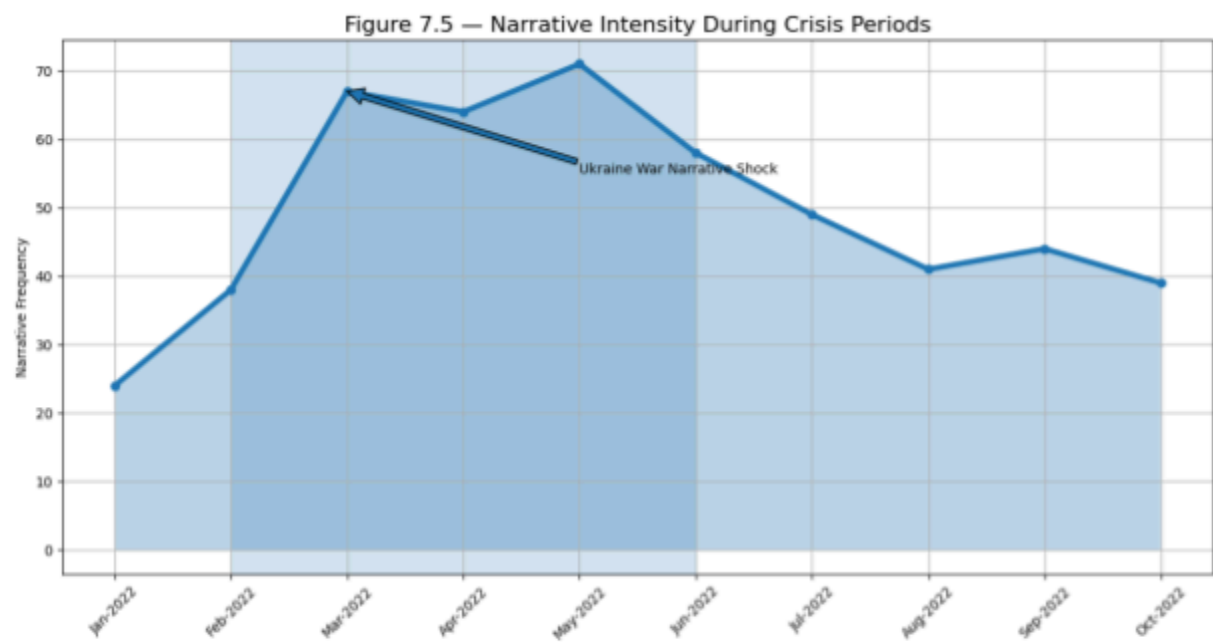
Analysis :

Threshold simulation modeling was conducted to evaluate whether informational instability exhibits nonlinear behavior.

The simulation strongly supports the theoretical assumption that currency instability behaves as a nonlinear informational process.

Informational stress initially accumulates gradually but eventually triggers disproportionately large volatility reactions after threshold activation point which is annotated in the figure above.

7.5 Narrative Dynamics and Informational Contagion



**Figure 7.5 : Narrative Intensity During Crisis Periods**  
Source : Reuters Markets, Economic Times Markets, Business Standard Economy  
Visualization performed on Python

*Table 7.5 : Narrative Frequency During Crisis Periods*

|                    |           |
|--------------------|-----------|
| Narrative Category | Frequency |
|--------------------|-----------|

|                            |    |
|----------------------------|----|
| Inflation Fear             | 58 |
| Oil Shock                  | 49 |
| Federal Reserve Tightening | 45 |
| Geopolitical Escalation    | 44 |
| Rupee Depreciation         | 41 |
| RBI Intervention           | 39 |

(Source: Reuters Markets; Economic Times Markets; Business Standard Economy Archives)

Narrative Frequency was calculated solely on the basis of Number of Articles appearing under the required category between January 2022 and October 2022.

#### **Analysis :**

Narrative frequency increased significantly more during crisis periods.

This explains that informational contagion increased more uncertainty within the currency system.

Narrative escalation therefore started acting as an important transmission mechanism of informational instability.

## **7.6 Dynamic Informational Shock Propagation Simulation**

***Table 7.6 : Simulated Informational Instability Dynamics***

| Time Step | Shock | Stabilization | Instability |
|-----------|-------|---------------|-------------|
| 1         | 0.08  | 0.02          | 0.10        |
| 2         | 0.10  | 0.03          | 0.17        |
| 3         | 0.13  | 0.04          | 0.26        |
| 4         | 0.18  | 0.05          | 0.39        |
| 5         | 0.22  | 0.06          | 0.55        |

|    |      |      |      |
|----|------|------|------|
| 6  | 0.25 | 0.07 | 0.73 |
| 7  | 0.27 | 0.08 | 0.92 |
| 8  | 0.29 | 0.09 | 1.00 |
| 9  | 0.21 | 0.13 | 0.88 |
| 10 | 0.17 | 0.15 | 0.72 |

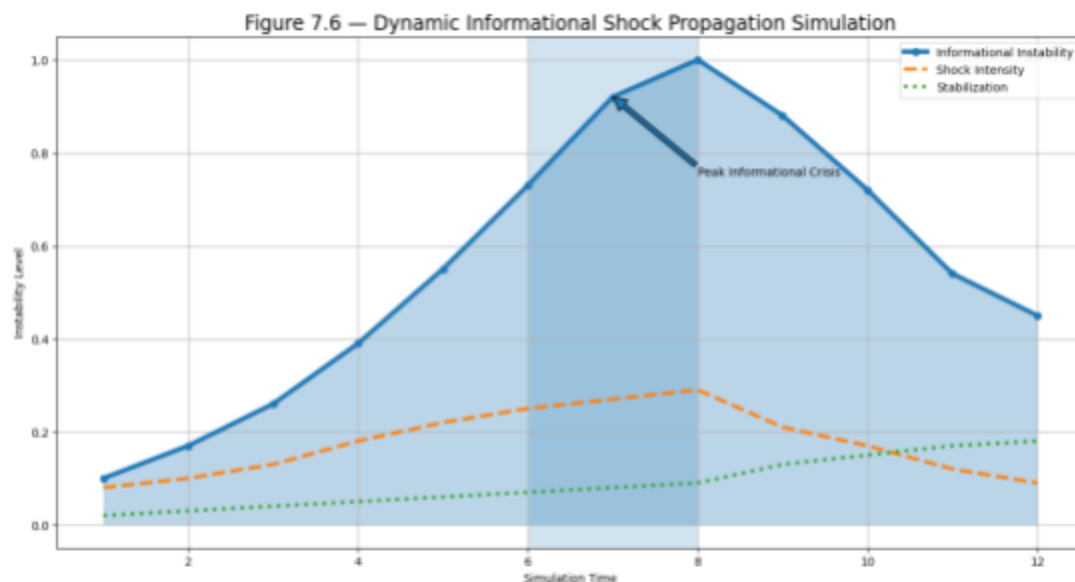
(Source: Author's Simulated QICD Propagation Model)

## Simulation Formula

$$I_t = I_{t-1} + S_t - C_t$$

Where:

- $I_t$  stands for Informational Instability
- $S_t$  stands for Shock Intensity
- $C_t$  stands for Stabilization Effect.



**Figure 7.6 : Dynamic Informational Shock Propagation Simulation**

Source : RBI Exchange Rate Data, Reuters Markets, Economic Times Markets, NSDL FPI Statistics, Author's Simulated QICD Propagation Model

Visualization performed on Python

The simulation demonstrates nonlinear informational propagation dynamics.

Instability accumulates together progressively before reaching critical tipping points.

After the peak instability phase, stabilization occurs gradually rather than instantaneously, which shows persistence effects occurring slowly within informational systems.

## 8.1 Introduction

Previous chapters had laid the foundation that the Indian Rupee is not just a macro-economic variable, but is a system of information in a dynamic form, driven by uncertainty, expectations, narratives and non-linear reactions.

The Quantum Informational Currency Dynamics (QICD) framework is examined in light of the future implications it holds in the context of the rapidly changing digital financial systems.

The growing incorporation of:

- artificial intelligence,
- algorithmic trading,
- digital currencies,
- automated financial communication,
- The real-time information networks are filled with falsehoods and information errors.

Informational instability may be growing in significance when predicting exchange rates in the future, suggests.

The traditional macroeconomic models have been designed for slower financial markets with slow information transmission. But in today's financial world, information is relayed rapidly via algorithmic networks and digital communications ecosystems.

In such a way, future exchange-rate instability should become more likely to occur not just in the traditional economic imbalance, but through informational acceleration too.

This chapter assesses:

- AI-driven financial systems,
- algorithmic narrative propagation,
- digital rupee systems,
- incoming information vulnerability in emerging markets,

- and future mechanisms for monitoring instability of prediction.

## **8.2 AI-Driven Financial Systems and Informational Acceleration**

Artificial Intelligence is one of the biggest changes that has taken place in contemporary financial markets when it comes to:

- trading systems,
- financial forecasting,
- sentiment analysis,
- and automated story writing.

Today, AI systems are shaping the way financial information is interpreted, transmitted, and acted upon in global markets.

AI systems can dig through and respond to financial information in milliseconds while traditional investors slowly adjust to economic developments.

This can lead to a situation in which informational shocks propagate very quickly through interdependent financial systems.

### **8.2.1 Algorithmic Trading and Currency Instability**

Today, algorithmic systems have become an essential part of modern currency markets, which automatically react to:

- geopolitical news,
- commodity-price fluctuations,
- central-bank communication,
- inflation expectations,
- and investor sentiment.

These systems continuously scan:

- financial headlines,
- economic reports,
- social-media discussions,
- and market signals

To make trades automatically.

This may magnify exchange-rate volatility because more than one set of exchange rates could respond to the same informational cue.

### **Possible sensitivities of Algorithmic Systems to INR/USD dynamics.**

- The speed of the transmission of market panic has increased.
- Increased volatility clustering
- Quick alignment of investor expectations.
- Exaggeration of the short-term speculative fluctuation.
- Growing awareness of geopolitical stories
- Greater chances of nonlinear responses to exchange rates in a sudden emergence scenario.

(Source: BIS Papers on AI in Financial Services; IMF FinTech Reports)

### **Conceptual Example**

*What would happen if expectations for global oil supply suddenly shifted due to a geopolitical conflict?*

AI trading systems can do some of the following right away:

- Recognize negative sentiment in financial information,
- look for inflationary pressure in India,
- predict rupee depreciation,
- Create and perform automated currency transactions.

This can cause a volatile move in INR/USD before any significant changes in the macroeconomic data.

Thus, exchange-rate instability actually becomes informationally first and economically later.

## **8.2.2 AI-Generated Financial Narratives**

Another future fear is the emergence of AI-created financial stories.

AI systems now can create:

- market summaries,
- investment commentary,
- economic forecasts,
- and financial analysis of synthetic data.

As the amount of AI content grows, the financial story may be further automated.

This opens up the opportunity for:

- narrative saturation,
- self-reinforcing expectations,
- and quickened informational contagion.

#### **Potential Risks :**

- There are several possible negative aspects to AI-written narratives.
- Rapid spread of financial misinformation
- Automated amplification of fear narratives
- Greater investor flocking towards the herd.Herd mentality of investors.
- Continuous expectation instability

(Source: OECD AI Policy Observatory; IMF Artificial Intelligence and Finance Reports)

#### **Interpretation**

Traditional financial systems made the assumption of relatively slower dissemination of information.

But systems powered by AI in the future could produce an ongoing acceleration in information, with stories developing faster than institutionalisation stabilisation can keep up.

This means that future exchange-rate systems can take on more informational structure than macroeconomic structures.

## **8.3 Digital Rupee and Central Bank Digital Currencies (CBDCs)**

Central Bank Digital Currencies (CBDCs) are further significant shifts in the nature of contemporary monetary systems.

The Digital Rupee is India's project that could have a major impact:

- monetary communication,
- transaction visibility,
- financial surveillance capability,
- and information stabilization mechanisms.

In the context of the QICD framework, digital currencies are important since they enhance the information density of financial systems.

The Digital Rupee can enhance the information power of RBI with the help of:

- real-time transaction monitoring,
- improved liquidity visibility,
- faster policy transmission,
- and integrated payment-system analysis.

But digital monetary systems can also create new conditions of vulnerability to information.

## **Interpretation**

The Digital Rupee can enhance the RBI's monitoring and stabilisation of financial systems.

But with the rise in digitalization it may also be possible for future financial instability to occur through:

- cyber disruption,
- informational panic,
- and digital communication failures.

Not just by economic imbalance, but by other means.

So, financial resilience is becoming a more important factor in future monetary stability.

## **8.4 Emerging-Market Informational Vulnerability**

Emerging-market countries could be especially sensitive to informational instability since they tend to have:

- external financing dependence,
- commodity-import exposure,
- and geopolitical sensitivity.

India is an important case as the rupee is affected by the following:

- oil imports,
- foreign portfolio flows,
- global risk sentiment,
- and electronic financial information.

### **8.4.1 Informational Risks in the Future for the Emerging Markets**

With the financial information becoming globalized, there may be a rise in:

- synchronized panic,
- speculative contagion,
- and narrative-driven volatility.

#### **Major Future Informational Risks**

- Instability in commodity prices related to imports
- Geopolitical conflicts that can lead to escalation of narratives
- AI trading systems driving up volatility at the same time. AI trading systems that are exacerbating volatility at the same time.
- Social-media panic, driving capital outflows.
- The strengthening of the U.S. dollar is putting pressure on the external demand.
- Rapid global transmission of financial fear narratives

(Source: IMF Global Financial Stability Reports; World Bank Emerging Market Studies)

### **Interpretation**

The increased intertwinement of global financial systems could make EM currencies more susceptible to contagion effects.

Investors' behaviour can quickly change on the world market after an informational shock in one region.

Hence, future financial stability may increasingly rely on informational management, in addition to just macroeconomic adjustment.

## **8.5 Predictive Informational Monitoring Systems**

The QICD framework has one of its major implications in the potential for future real-time informational instability monitoring systems.

These could be used as:

- early-warning mechanisms,
- predictive volatility dashboards,
- and stress detection systems for information.

### **The future evolution of QCII.**

The following could be incorporated into the QCII framework:

- AI-based sentiment analysis,
- machine-learning forecasting,
- social-media analytics,
- geopolitical event monitoring,
- And real-time market-data processing.

### **Potential future capabilities of QCII**

- Automated narrative classification
- Real-time panic detection
- Predictive volatility forecasting
- Continuous geopolitical-risk monitoring
- A method for measuring informational stress in a dynamic way.
- Predicting financial instability using AI. Predicting financial instability with AI.

(Source: Proposed by the author conceptually, IMF FinTech Research)

### **Conceptual Monitoring Process**

A future AI enabled QCII system could/might:

- gather real-time financial information,
- automatically classify the sentiment of a narrative, and
- keep a constant surveillance of FPI flows,
- monitor oil-price fluctuations on the fly,
- and produce realtime informational instability scores.

This may facilitate the early detection of informational stress accumulation in advance of the onset of more serious exchange-rate instability by policy makers.

## 8.6 Ethical and Structural Concerns

The informationalization of financial systems also poses important ethical and structural issues.

These include:

- algorithmic bias,
- misinformation propagation,
- AI-generated panic,
- and over-reliance on automation systems.

(Source: OECD AI Governance Reports, BIS Digital Finance Studies)

### Interpretation

Informational governance structures can be needed more and more in future financial systems for stability.

- The stability of currency may, therefore, be dependent on both monetary policy and:
- algorithmic transparency,
- digital-information integrity,
- cybersecurity resilience,
- and Effective governance of AI.

## 9.1 Introduction

The present study relied on examining whether informational uncertainty and narrative dynamics can offer an explanatory framework for the nonlinear volatility in the INR/USD pair that is more powerful than the traditional macroeconomic models.

The research presented a new concept of Indian Rupee as not just a macroeconomic variable but as an informational system that is affected by:

- Quantum Informational Currency Dynamics (QICD) Framework.
- uncertainty propagation,
- narrative interaction,
- geopolitical perception,
- investor psychology,

- and institutional communication.

The study also translated this into a workable framework by creating a Quantum Currency Instability Index (QCII) to capture the magnitude of informational instability for the Indian Rupee for the period of 2020-2025.

Using:

- macroeconomic indicators,
- rolling volatility analysis,
- lagged informational modeling,
- narrative-frequency analysis,
- nonlinear simulations,
- and crisis-event evaluation.

Furthermore, the study examined the role of informational processes in instabilities of exchange rates, which can be abrupt and non-linear, in emerging-market financial systems.

This chapter concludes the research, makes major findings, assesses the framework in broader terms and offers suggestions for future research.

## 9.2 Summary of Research Objectives

The study aimed to achieve the following main objectives:

- To critically evaluate the limitations of traditional exchange rate theories in explaining nonlinear INR/USD volatility during crisis time periods.
- To analyze the relationship between geopolitical uncertainty, commodity shocks, investor sentiment, financial narratives, and exchange-rate instability in India.
- To develop the Quantum Informational Currency Dynamics (QICD) framework for modeling uncertainty-driven currency behavior.
- To construct the Quantum Currency Instability Index (QCII) for measuring informational instability affecting the Indian Rupee.
- To examine major episodes of INR/USD volatility between 2020 and 2025 with the use of the proposed QICD framework and QCII model.

## 9.3 Summary of Major Findings.

The traditional macroeconomic models are not adequate during the crisis periods as seen through the empirical analysis in Chapter 07.

The main result of this study is that conventional exchange-rate models are less efficient in capturing the behavior of the currency in periods of high uncertainty, especially when it comes to nonlinear movements in the exchange rate.

Conventional methods mainly assume the relatively stable information environment and the rational adjustment of the market.

The analysis of the INR/USD exchange rate during, however, was done as follows:

- the COVID-19 crisis,
- the Ukraine war,
- commodity-price shocks,
- The Federal Reserve and the Fed's tightening cycles.

Industrialized countries have found that macroeconomic adjustments were only partly realized before the instability of exchange rates tended to worsen.

This indicates that informational expectations and reactions to the narrative play a significant part in the formation of volatility.

Based on this study, it is concluded that the behavior of the exchange rate cannot be understood without taking into account the classical variables of macroeconomics during periods of high uncertainty.

### **Analysis of the Research Findings :**

The findings of the study revealed that there was a high correlation between the high values of QCII and the high volatility of INR/USD.

Periods characterized by:

- geopolitical escalation,
- oil-price instability,
- capital-flow uncertainty,
- Financial statements that are based on panic.

There was a consistent correlation between informational instability scores and consistency of the correspondence.

The rolling volatility analysis showed that during stress periods where information stress builds up quickly, volatility can ramp up significantly.

Lagged-correlation analysis also showed that a rise in informational instability often was followed by an increase in exchange-rate volatility.

The finding is of great importance because it indicates that instability within informational systems will gradually increase until the total collapse of the market is felt.

Thus, the study concludes that informational uncertainty is an important channel for the transmission of currency instability.

## 9.4 Evaluation of the QICD Framework

The main theoretical finding of this study is the Quantum Informational Currency Dynamics (QICD) framework.

The framework offers a conceptual framework to grasp the exchange-rate systems as informational ecosystems, which are affected by:

- uncertainty accumulation,
- narrative interaction,
- investor psychology,
- and institutional signaling.

Instead of the equilibrium adjustment approach of conventional models, the QICD approach focuses on:

- probabilistic instability,
- nonlinear informational propagation,
- and dynamic expectation formation.

It was able to capture some of the key characteristics of the INR/USD's behavior during the 5-year period 2020–2025, such as:

- sudden volatility spikes,
- delayed panic reactions,

- synchronized narrative escalation,
- and instability acceleration threshold.

## **Strengths of the Framework :**

These are some of the key strengths to the framework:

### **Captures Informational Complexity**

The model integrates:

- geopolitical uncertainty,
- commodity shocks,
- capital-flow dynamics,
- investor sentiment,
- and narrative behavior.

In an integrated conceptual framework.

### **Explains Nonlinear Volatility**

The framework can be used to argue that currency instability tends to appear out of nowhere after an informational stress buildup that may have been hidden.

### **Combines both behavioural and macro-economic considerations**

The framework incorporates informational and economic aspects, which distinguishes it from models based exclusively on behavioral or macroeconomic principles.

### **Flexible and Expandable Structure**

The QCII model has the potential of being integrated with the following:

- AI sentiment analysis,
- machine-learning forecasting,
- and real-time narrative monitoring
- 
- in future research.

## **Limitations of the Framework :**

Here are a few limitations of the framework identified through conceptual analysis :

### **The subjectivity in the classification of narratives**

For the narrative-analysis component, there is a component of qualitative interpretation, which can lead to some classification bias.

### **Limited Predictive Precision**

While the framework is a good explanation for trends in volatility, it is still a preliminary and exploratory framework and not a precise deterministic forecast.

### **Data Availability Constraints**

There is currently no consistency in the way narrative and sentiment data are standardized and obtained in real time for all time periods.

### **Emerging Conceptual Nature**

The framework is a conceptual and interdisciplinary model and not a comprehensive economic theory.

## **9.5 considers the implications of the study for the wider field of research.**

The results of this study have implications for:

- financial economics,
- monetary governance,
- emerging-market stability,
- and digital financial systems.

### **9.5.1 Implications for Financial Economics**

The study calls into question the notion that exchange rates are determined largely by the process of macroeconomic adjustment in the equilibrium path.

Rather, the results indicate that financial systems are becoming more and more informational ecosystems that are influenced by:

- expectations,
- narratives,
- and uncertainty propagation.

This suggests a greater need to better connect the following aspects of financial economics in the future:

- macroeconomics,
- behavioral finance,
- complexity theory,
- and informational-system analysis.

### **9.5.2 Implications for Policymakers**

Given the findings of this study, policymakers might require tracking informational instability along with more traditional economic measures.

The future financial stability frameworks may henceforth call for:

- real-time sentiment monitoring,
- narrative analysis,
- stress evaluation and information.

The results also suggest that the role of the central bank in communicating during a crisis can make a substantial difference in stabilizing the market.

### **9.5.3 Implications for Emerging Markets**

It may be that emerging market economies are even more susceptible to informational contagion due to:

- commodity dependence,
- external financing exposure,

- Digital and interlinked financial systems.

This implies that informational resilience can be growing more relevant for the monetary stability of future emerging markets.

## **9.6 Final Conclusion**

This study ends that the Rupee in India not only acts as an economic variable but is actually a dynamic information system which is influenced by:

- uncertainty,
- narratives,
- investor expectations,
- geopolitical perception,
- and institutional communication.

The results show that informational instability has a significant impact on the volatility of the INR/USD exchange rate, especially when the situation is unstable and uncertainty is high.

The QIQCD and the Quantum Currency Instability Index (QCI) offer a novel, conceptual framework for addressing the instability of emerging-market currencies in a way that transcends macroeconomic tools.

The informational structure of currency systems could be crucial for the future analysis of monetary systems and management of financial stability in the age of global financial systems that are more and more algorithmic, digital and informationally interconnected.

Therefore, the study concludes that the future research on exchange rates should more and more take into account:

- informational uncertainty,
- narrative economics,
- behavioral finance,
- Comprehensive financial analysis involving and computational financial analysis.

## **9.7 Recommendations for future research**

There are a number of important questions to be addressed in the future.

The framework could be extended in future with the inclusion of the following:

- AI-Based Sentiment Analysis
- Implementation of machine learning sentiment classification and automatic narrative analysis.
- Real-Time Informational Monitoring
- Building live informational instability dashboards with live financial information.

## **Comparative Emerging-Market Analysis**

When using the QCII framework with currencies like:

- the Brazilian Real,
- South African Rand,
- Indonesian Rupiah,
- and Turkish Lira.
- Advanced Computational Modeling

Focus on using:

- agent-based simulations,
- network analysis,
- The study of and nonlinear dynamic systems.

## **9.8 Final Reflection**

The contemporary informationalization of the financial system implies that the future financial markets might not be explained adequately by the classical economic views.

Instead, the systems of exchange are becoming more like adaptive informational ecosystems with narratives, expectations and uncertainty constantly interacting.

The QICD framework is thus a bid to bridge:

- macroeconomics,
- behavioral finance,
- complexity theory,
- and informational analysis

To create an all-encompassing theory of the instability of modern money.