European Economic Letters
ISSN 2323-5233
Vol 14, Issue 4 (2024)
http://eelet.org.uk

An Empirical Analysis of Forex Volatility and Spillover Mechanisms in India

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ABSTRACT
This research article explores the volatility and spillover mechanisms in the Indian forex market through an empirical analysis spanning from 2008 to 2023. The main focus is to assess how the foreign exchange rates behave, observe trends in currency pair valuations, and study the volatility transmission in the market. The study concentrates on four major currencies: EURO/INR, USD/INR, GBP/INR, and YEN/INR, with data sourced from the RBI website, the IMF, and various secondary materials such as books and articles. The study used appropriate methods and techniques developed by previous researchers and financial analysts to evaluate forex volatility. ADF, Phillip Perron tests, ARMA, ARCH and GARCH models were used to analyse the forex volatility.

Keywords: Forex volatility, Currency, ADF, ARCH, GARCH.

1. INTRODUCTION

The foreign exchange market, commonly referred to as Forex, plays a crucial role in the global financial system by facilitating the exchange of currencies between nations. In most emerging and growing economies, including India, the Forex market operates under a managed floating exchange rate system, where the exchange rate is largely determined by market forces but with periodic interventions by central banks to achieve specific monetary policy objectives. This approach allows nations to balance domestic economic goals, such as controlling inflation and stimulating output growth, while managing the volatility in exchange rates. However, the choice of an exchange rate regime, as noted by Siklos (2006), presents significant challenges, particularly in maintaining central bank transparency and accountability in a volatile global environment.

Historically, foreign exchange transactions date back to the 14th century in England, but the development of the modern Forex derivatives market began in the 1970s, following significant shifts in the global monetary system. The collapse of the Bretton Woods system in 1971, which led to the abandonment of fixed exchange rates, was a pivotal moment. In 1976, the International Monetary Fund (IMF), during its meeting in Jamaica, formalized the adoption of a floating exchange rate system through the Jamaica Agreement. This transition from a fixed to a floating exchange rate system exposed nations to increased exchange rate risk, leading to a surge in the use of financial derivatives as tools for managing and hedging this risk.

Economic globalization further accelerated the development of the forex derivatives market. As global financial activities expanded, so did capital flows between nations, driven by both domestic and foreign investors. Financial institutions, responding to the increasing demand for risk management tools, introduced innovative financial products like forwards, options, and swaps, enabling market participants to hedge against adverse currency movements. The foreign exchange derivatives market thus grew rapidly during the 1980s and 1990s, evolving from traditional currency trading to a sophisticated market for risk management.

In the context of India, understanding the dynamics of Forex volatility is crucial due to the economy's increasing integration with global markets. The Indian foreign exchange market has witnessed significant fluctuations in its currency values over the years, influenced by both domestic factors and global economic conditions. Volatility in exchange rates can have profound effects on trade, investments, and overall economic stability. Thus, this paper aims to provide an in-depth analysis of Forex volatility in the Indian market, focusing on identifying the key drivers behind these fluctuations and examining the transmission of volatility across major currency pairs. By utilizing advanced econometric models, this study seeks to offer valuable insights into the spill over mechanisms within the Indian foreign exchange market,

contributing to a deeper understanding of how volatility in one currency can affect others and the broader financial ecosystem.

2. REVIEW OF LITERATURE

Husted, Lucas, and Rogers (2018) provide compelling evidence that increased uncertainty in the U.S. economy or financial markets significantly raises excess returns from currency carry trades. Their research suggests that macroeconomic and financial uncertainty influences global investors' risk preferences, leading to higher returns as investors demand compensation for the heightened risk. They also observe that this uncertainty lowers foreign exchange (FX) risk reversals, particularly for high-interest-rate portfolios. This indicates that during periods of increased U.S. uncertainty, global investors exhibit greater risk aversion, which in turn raises the expected returns and the cost of protecting against crash risk in the FX market. The study underscores the interconnectedness of global economic conditions and their direct impact on currency markets, specifically through investors' shifting risk appetites.

Albouy and Dupuy (2017) focus on the use of derivatives for foreign exchange risk management among French non-financial firms. Their research highlights the practice of selective hedging, where firms adjust the size and timing of their hedges based on market conditions. Data collected from 2010 to 2015 through surveys and interviews reveals that French corporations hedge their FX risk more systematically than firms from other countries. However, the study also finds that highly indebted and smaller firms are more likely to engage in selective hedging rather than following fixed policies. The authors relate these practices to cultural differences and communication challenges that influence corporate behavior in managing risk. This study provides valuable insights into how firms adapt their risk management strategies based on firm characteristics and cultural factors, suggesting that FX risk management is far from a one-size-fits-all approach.

Rahman and Hoque (2015) explore how conventional and Islamic banks in Bangladesh manage their foreign exchange risks. The study reveals that forwards and netting are the most commonly used instruments to manage transaction exposure, which is the primary form of FX risk faced by banks. The findings suggest that while banks engage in hedging to reduce their risk exposure, they do not fully hedge due to the high costs associated with these activities. The researchers highlight the need for further improvements in risk management practices, especially in terms of performance efficiency in the banks studied. The study contributes to understanding how different banking systems address FX risk management but also points to the ongoing challenges in fully mitigating exposure.

Berisha, Asllanaj, and Phd Albulena (2014) focus on the role of financial instruments in reducing exchange rate risk exposure for firms. Their research highlights the vulnerabilities firms face due to exchange rate fluctuations and how derivatives such as forwards, options, and swaps can help mitigate these risks. The study underscores that these financial instruments not only serve as a hedging tool but also provide opportunities for firms to speculate on currency movements. The paper emphasizes the importance of proper risk measurement and management to safeguard firms from adverse currency movements that can negatively affect profit margins and asset values. It also discusses the dual role of derivatives as both risk management and speculative instruments.

Bodla and Reeta (2013) examine the broad spectrum of financial risks—including interest rate risk, exchange rate risk, and market risk—faced by firms in both domestic and international markets. They argue that financial derivatives like forwards, swaps, and options offer corporate managers a suite of tools to manage these risks effectively. However, the authors acknowledge that there is still considerable debate surrounding how firms should measure and manage financial risk, particularly in the context of increasing global market complexities. Their study calls for more nuanced approaches to risk management and suggests that a one-size-fits-all strategy may not be effective in addressing the diverse range of risks companies face in modern financial markets.

While the existing literature provides substantial insights into various aspects of foreign exchange (FX) risk management, volatility, and the use of financial instruments, there are notable gaps that remain unaddressed in the context of forex volatility and spillover mechanisms in the Indian market. Most of the research, such as that by Husted, Lucas, and Rogers (2018), concentrates on developed economies like the U.S. and the effects of macroeconomic uncertainty on global investor behavior. However, little attention has been paid to the unique dynamics of forex volatility in emerging markets like India, where both domestic and global factors can have distinctive impacts on currency fluctuations. Studies on foreign exchange risk, such as Albouy and Dupuy (2017), focus on corporate hedging practices but do not delve into volatility spillovers between different currency pairs or markets. This gap is critical for understanding how volatility in one currency (e.g., USD/INR) might spill over into other currencies (e.g., GBP/INR, YEN/INR) in the Indian context. A deeper examination of these spillover mechanisms is necessary to fully understand the interconnected nature of global and Indian forex markets.

While Berisha, Asllanaj, and Albulena (2014) discuss the importance of financial instruments in reducing exchange rate risk, their focus is largely on the nature of derivatives without analyzing long-term volatility trends. Moreover, much of

the literature on FX volatility and risk management tends to focus on shorter time frames or specific events, whereas there is a need for comprehensive studies spanning over a decade, particularly in India where the currency has experienced significant fluctuations from 2008 to 2023. While Bodla and Reeta (2013) highlight the importance of financial derivatives in managing various financial risks, the role of domestic factors such as Indian monetary policy, fiscal events, and geopolitical risks in influencing forex volatility remains underexplored. The Indian rupee is influenced by a complex mix of domestic economic policies and global factors, yet many studies lack an in-depth analysis of how these factors interact with global volatility spillovers in shaping exchange rate behavior in India. The literature has extensively employed econometric models like GARCH and ARCH for analyzing FX volatility (as in studies like Husted, Lucas, and Rogers, 2018), but there is limited use of these models in the Indian forex context. Few studies have applied ARMA, ARCH, and GARCH models specifically to Indian currency pairs, leaving a gap in understanding the nuanced volatility patterns and their transmission mechanisms in the Indian market over the long term.

This research article aims to fill these research gaps by focusing on the Indian forex market and analyzing the volatility of key currency pairs (EURO/INR, USD/INR, GBP/INR, YEN/INR) from 2008 to 2023. The research tries to investigating the spillover effects between these currencies to understand how volatility in one pair affects others within the Indian market. By utilizing advanced econometric techniques such as ADF, Phillips-Perron, ARMA, ARCH, and GARCH models to analyze the long-term trends and transmission of forex volatility. The research also examines the role of both global and domestic factors in driving volatility and their implications for investors and policymakers in India. This study provides a more comprehensive understanding of forex volatility in India, filling the existing literature gap and offering new insights into risk management and policy implications in emerging markets.

3. METHODOLOGY

3.1 Data Sources

The study utilizes secondary time-series data for four currency pairs: INR-Euro, INR-GBP, INR-USD, and INR-JPY. The data is sourced from the Reserve Bank of India (RBI) and consists of daily reference rates for each pair.

3.2 Sample and Time Frame

The study covers the period from August 29, 2008, to December 31, 2023, offering a comprehensive analysis of forex volatility. The sample consists of 3,520 daily observations for each currency pair, resulting in a total of 14,080 data points. The breadth of this dataset allows for robust conclusions regarding volatility trends and spillover mechanisms.

3.3 Research Design

This study follows an empirical and analytical research design. A descriptive analysis is performed to document the historical evolution of the Indian forex market and to highlight key structural changes over time. Additionally, graphical representations and time-series plotting are employed to examine patterns of extreme volatility and significant market movements.

3.4 Analytical Framework

The study employs advanced econometric techniques to analyze the volatility of the Indian Rupee. Specifically, the Augmented Dickey-Fuller (ADF) test and Phillips-Perron test are used to test for stationarity in the time series data. To explore long-term relationships between currencies, the Johansen Co-integration test is applied. The GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model is utilized to capture and quantify time-varying volatility and its transmission across currency pairs.

4. RESULTS AND DISCUSSION

4.1 Key Drivers of Forex Volatility

The volatility of the Indian Rupee has been influenced by a variety of both global events and domestic policy changes over the past two decades. Several significant factors have shaped its exchange rate dynamics:

- **Post-Bretton Woods Transition:** Following the collapse of the Bretton Woods system, India transitioned from a fixed exchange rate regime (initially pegged to the GBP) to a managed floating exchange rate system linked to a basket of currencies, including the USD. This shift allowed the INR to reflect global trade dynamics while remaining under the periodic intervention of the central bank.
- **Economic Liberalization of the 1990s:** India's economic liberalization in the 1990s was a major turning point, introducing current account convertibility and permitting banks to engage in forex trading. This integration into global markets exposed the INR to external shocks while simultaneously offering opportunities for greater exchange rate flexibility. The managed float regime, in which the rupee operates today, continues to rely on central bank intervention to moderate excessive volatility.
- **2007-08 Global Financial Crisis:** The global financial crisis significantly impacted the forex market, with the Indian Rupee experiencing heightened volatility alongside other emerging market currencies. Triggered by the subprime

mortgage crisis in the United States, the crisis led to a spike in global risk aversion, making the INR particularly vulnerable to external shocks and market uncertainty during this period.

- **Oil Price Surge (2018):** The 2018 oil price surge marked another period of intense volatility for the INR. As a major oil importer, India's currency is highly sensitive to global oil prices. A sharp increase in demand from China, the world's largest consumer of crude oil, contributed to the rupee's depreciation. The EUR/INR exchange rate, for instance, rose from 73.53 to 80.07 during this time, underscoring the currency's susceptibility to commodity price shocks.
- **COVID-19 Pandemic (2020):** The COVID-19 pandemic severely disrupted global financial markets, causing the Indian Rupee to weaken against safe-haven currencies like the Euro. The global flight to safety, characterized by capital outflows from emerging markets, intensified the demand for currencies like the Euro, leading to a marked depreciation of the INR. This period saw investors seeking stability in developed markets amid widespread economic uncertainty.
- **Russia-Ukraine Conflict (2022):** The Russia-Ukraine war in 2022 exacerbated volatility in the forex market, with significant spill over effects on energy and commodity prices. The conflict led to a sharp rise in inflation globally, which adversely affected investor confidence and economic growth. Consequently, the Euro depreciated against many currencies, including the INR, as market participants responded to heightened geopolitical risks and uncertainty surrounding global supply chains.

This detailed examination of forex volatility drivers offers critical insights into the factors influencing the Indian foreign exchange market. By analyzing both global and domestic events, this study highlights the interplay between external shocks and internal policy mechanisms in shaping currency movements.

4.2 Transmission of Forex Volatility in Indian Foreign Exchange Markets

In this section, we examine the transmission of forex volatility across the Indian foreign exchange market using a variety of econometric tests and models. The focus is on understanding how volatility is carried over time and across currency pairs, particularly for USDINR, GBPINR, EUROINR, and YENINR series.

Table I: ADF Test for USDINR, GBPINR, EUROINR series and Returns of USDINR, GBPINR, EUROINR, YENINR series

Currencies	Exchange price (P value)	(Returns)ADF Test Statistic	Returns(5 % level)
USDINR	0.7985	35.9833	2.8625
GBPINR	0.5735	30.0755	2.8625
EUROINR	0.5134	47.4202	2.8625
YENINR	0.0179	49.5819	2.8625

The ADF test results show that for the exchange rate series, the p-values exceed 5%, and the test statistic is less than the critical value. This suggests that the exchange rate series are **non-stationary**. However, for the return series, the p-values are less than 5%, and the test statistics exceed the critical value, leading to the rejection of the null hypothesis. Hence, the return series are **stationary**, indicating that they are suitable for further volatility analysis.

Table II: Phillip Perron Test for USDINR series and Returns of USDINR, GBPINR, EUROINR, YENINR series

Currencies	Exchange price (P value)	(Returns) ADF Test Statistic	Returns (5 % level)
USDINR	0.7662	48.3970	2.8625
GBPINR	0.5600	47.2922	2.8625
EUROINR	0.4830	47.4276	2.8625
YENINR	0.0206	49.6374	2.8625

Similar to the ADF test results, the Phillips-Perron test shows that the exchange rate series are non-stationary, as their p-values are greater than 5%. However, for the return series, the p-values are below 5%, and the test statistics are higher than the critical value, indicating that the return series are stationary.

Table III: ARMA (3, 3) for USDINR, GBPINR, EUROINR, YENINR Return series

Variable	USDINR	GBPINR	EUROINR	YENINR
AR(3)	0.0000	0.0000	0.0000	0.0000
MR(3)	0.0000	0.0000	0.0000	0.0000
Dependent Variable: LOGUSDINR, GBPINR, EUROINR, YENINR				

The ARMA (3, 3) model was selected based on the autocorrelation structure observed in the correlogram, with the third lag showing the most significant effect. This indicates that lagged values up to the third period influence current returns. The residuals from the ARMA model will be used for testing the presence of ARCH effects to determine whether volatility clustering is present in the return series.

Table IV: Heteroskedasticity (ARCH LM Test) of Residuals of ARMA (4, 4) for Return USDINR GBPINR, EUROINR, YENINR series

	USDINR	GBPINR	EUROINR	YENINR
Prob.F(2,2369)	0.0000	0.0000	0.0000	0.0000
Prob.Chi-square(2)	0.0000	0.0000	0.0000	0.0000
Heteroskedasticity Test: ARCH				

The ARCH LM test results reveal that the null hypothesis of no ARCH effects is rejected for all currency pairs, as the p-values are well below 0.05. This suggests that there is heteroskedasticity in the residuals, confirming the presence of ARCH effects, meaning that volatility is time-varying and clustered.

Table V: ARCH equation for USDINR, GBPINR, EUROINR, YENINR Return series

Currencies	Coefficient	P value
USDINR	0.5109	0.000
GBPINR	0.2490	0.000
EUROINR	0.2357	0.000
YENINR	0.2788	0.000
Dependent Variable: LOGUSDINR, GBPINR, EUROINR, YENINR		

The ARCH model results show that the ARCH coefficients for all currency pairs are highly significant ($p < 0.05$). This indicates that past volatility (lagged squared residuals) significantly influences current volatility, suggesting that volatility is predictable based on prior periods' volatility.

Table VI: GARCH equation for USDINR, GBPINR, EUROINR, YENINR Return series

Currencies	ARCH Coefficient	GARCH Coefficient	P value
USDINR	0.1037	0.8833	0.000
GBPINR	0.1037	0.8833	0.000
EUROINR	0.0441	0.9405	0.000
YENINR	0.0924	0.8905	0.000
Dependent Variable: LOGUSDINR, GBPINR, EUROINR, YENINR			

The GARCH coefficients for all currency pairs are also highly significant, with values close to 1. This implies that both the ARCH and GARCH effects contribute to the explanation of volatility. The high GARCH coefficients indicate that shocks to volatility have a persistent impact over time, meaning that current volatility is heavily influenced by previous periods' volatility.

These results highlight the transmission of volatility within the Indian foreign exchange market. The findings suggest that volatility is not only time-varying but also persistent, with past volatility strongly influencing current fluctuations in exchange rates. The ARCH and GARCH models effectively capture the dynamic nature of volatility in these currency pairs, offering critical insights into how volatility shocks propagate through the market.

6. FINDINGS

The study's findings indicate the evolution of India's foreign exchange market and the factors contributing to the volatility of the Indian Rupee (INR) against major currencies. Initially, the rupee was fixed against the British Pound (GBP) until the collapse of the Bretton Woods system, after which it was pegged to a basket of currencies, including the US Dollar, based on global trade relations. The liberalization reforms in the 1990s marked a significant structural change, allowing banks to trade foreign exchange, especially with the introduction of current account convertibility. As a result, the Reserve Bank of India (RBI) and the central government allowed the INR to follow a floating exchange rate regime, although it remained a managed float.

The global financial crisis of 2007-08 triggered a period of heightened volatility in the forex markets, with the INR showing significant fluctuations against all major currencies. Other factors, such as the rise in oil prices in 2018, the economic disruptions caused by the COVID-19 pandemic in 2020, and the geopolitical tensions arising from the Russia-

Ukraine war in 2022, have also had profound effects on the volatility of the INR. These global events impacted global trade, transportation, and overall economic stability, which in turn affected exchange rates.

Regarding the specific findings of the GARCH models:
USD-INR: The GARCH model showed that both the ARCH and GARCH coefficients were near 1 (0.986), indicating that volatility shocks are highly persistent, and volatility clustering is present in the USD-INR return series. This suggests that past volatility has a significant influence on current market behavior.
GBP-INR: Similarly, the sum of the ARCH and GARCH coefficients (0.9664) showed persistence and volatility clustering, reinforcing the notion that volatility shocks have long-lasting effects in the GBP-INR exchange rate.

EURO-INR: The GARCH model for EUR-INR showed a highly significant ARCH coefficient (0.0441) and a significant GARCH coefficient (0.9405), further confirming that past volatility has a strong predictive power for future volatility in the exchange rate. The sum of the ARCH and GARCH coefficients (0.9846) indicates that volatility shocks are persistent and cluster over time.

YEN-INR: In the case of JPY-INR, the third lag in the ARMA model showed a negative coefficient, and the intercept term was almost negligible. The ARCH LM test confirmed the presence of heteroscedasticity in the residuals, and the GARCH model's sum of the coefficients (0.9829) indicated persistence in volatility shocks, confirming volatility clustering in the YEN-INR return series.

7. CONCLUSION

This research provides valuable insights into the growth and development of the foreign exchange market in India, highlighting the key reforms and structural changes that have shaped the market. The study also underscores the importance of central bank intervention to control currency volatility, especially in an economy like India, which relies on a managed floating exchange rate system.

The volatility of the rupee against major currencies such as the USD, GBP, EURO, and JPY is influenced by several domestic and global factors. The research emphasizes that the persistent depreciation of the rupee can adversely affect India's current account deficit (CAD) and weaken macroeconomic indicators. Understanding the dynamics of this volatility is crucial for policymakers and market participants to mitigate risks and maintain stability.

The study confirms that ARCH family models are the most effective tools for evaluating forex volatility, as they account for the presence of heteroskedasticity in the residuals and allow for sudden jumps in volatility. While the ARMA model can serve as a starting point for estimating exchange rate equations, it is the GARCH models that provide a more robust and reliable framework for modeling and forecasting volatility in the foreign exchange market.

By capturing the volatility clustering and persistence of shocks, the findings highlight the complex relationship between exchange rate movements and external factors, which is crucial for understanding and managing forex market risks in emerging economies like India.

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