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Price discovery and volatility spillovers in the Indian currency futures and spot markets: Before and during the COVID pandemic

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ABSTRACT

This research aims to examine the price discovery and volatility spillover effect in Indian currency spot and futures prices. The study uses minute-wise data of spot and futures prices of USD/INR traded on the National Stock Exchange (NSE), India. The sample data is divided into two sub-periods: pre-COVID-19 (August 1, 2019 to January 24, 2020) and COVID-19 (January 25, 2020 to August 31, 2020). Data is analysed using the Autoregressive Distributed Lag (ARDL) approach and multivariate MGARCH Diagonal VECH model. The ARDL results reveal a bidirectional causation between the two markets for both sample periods, with a greater lead of the spot market in price discovery. Further, the MGARCH model shows a two-way volatility spillover between the markets. The spillover effect from the currency spot to the futures market is more substantial during the prior outbreak of the COVID-19 pandemic. Results indicate no asymmetric effect in the volatility dynamics of spot and futures prices. The study suggests that the currency spot market contributes to price discovery and volatility spillover effects in the pre-and COVID-19 pandemic. These findings provide crucial insights for hedgers, arbitrageurs and speculators to form trading strategies that mitigate against downside risk in their investment portfolios.

INTRODUCTION

Futures markets serve as vital tools for hedging and price discovery. Hedging reduces risks from price fluctuations by offsetting losses in the spot market with futures profits, as both markets typically move together. Price discovery in futures reflects information from underlying markets, resulting in a temporal relationship between spot and futures prices. Determining how quickly one market reacts to new information originating from the other becomes crucial. It is widely viewed that the futures markets are dominated by the price discovery mechanism due to the lower margin requirements and greater liquidity (Garcia et al. 2014). This helps hedgers take a competitive advantage over future prices and reduce risk. Furthermore, the new information is incorporated into spot prices faster than future prices (Rosenberg and Traub, 2007). The price discovery process would assist hedgers in formulating better trading and hedging strategies to manage risks against adverse price movements. Arbitrageurs can gain from short-term disequilibrium by exploiting the price discrepancy between the spot and futures markets. Speculators develop more profitable trading strategies, while regulators can implement corrective measures to enhance market integrity and efficiency.

Volatility spillovers between spot and futures markets play a crucial role in forecasting future volatility. The volatility spillover hypothesis posits that the volatility spillovers are coupled with asymmetries; a bad news shock in either market can increase volatility and its persistence in both markets (Tao & Green, 2012; Gkillas et al. 2021). Futures prices react to new information quickly during the price discovery process, leading to increased volatility in the underlying spot market price due to the arbitrage mechanism (Malhotra & Sharma, 2016). If the spot market is informationally efficient, spot price changes will increase volatility in the futures market. Therefore, volatility spillover serves as a significant source of information, enabling the examination of how volatility in the futures market affects the spot market or vice versa (Seghal et al., 2015). Besides, the various macroeconomic factors, including GDP growth, RBI rates, interest rates, trade balances, fiscal policies, and inflation, influence the spillover effects in currency derivatives markets. By considering these indicators, market participants can better understand the fundamental drivers of currency values, anticipate leading markets, and make informed trading decisions in currency derivatives markets (Chatrath and Song., 1998). Moreover, the price discovery process and spillover effects observed in the spot and futures markets necessitate the utilization of a volume-based sentiment index to justify the reactions of the market participants. Investor sentiment strongly influences the dynamics of these markets at any given moment (Corredor et al., 2015).

According to the RBI Bulletin (2020), the COVID-19 pandemic, much like previous episodes of extreme volatility in financial markets—such as the global economic crisis, the Eurozone crisis, and the Taper Tantrum—led to significant foreign exchange outflows from emerging markets, including India. In March 2020, India experienced unprecedented foreign portfolio investment outflows, amounting to US$15.92 billion across debt and equity instruments and led to increased volatility in the Indian Rupee (INR). Daily depreciation of upto 1 percent was observed multiple times during March 2020. Besides, the COVID-19 pandemic has triggered unprecedented disruptions in global trade, leading to currency depreciation due to market sentiments in India (Padhan & Prabheesh, 2021). The continuous weakening of the US Dollar/INR due to COVID-19 has raised investor concerns about the dynamics of the price discovery process and spillover effect of currency futures and spot markets in India. Understanding the periodic nature of price discovery and volatility spillover effects is essential for market participants, particularly in assessing the direction of information transmission between spot and futures prices. Moreover, analyzing the dynamics of these markets during the pre-COVID and COVID pandemic periods is crucial for regulators and policymakers to respond to any future pandemic. This research adds to the body of knowledge in several ways. First, the study explores price discovery and volatility spillover effects of the Indian currency market using minute-by-minute data. It provides fresh insights into the existing domain of scholastic literature, apart from contributing to the policy dimension of price risk management to facilitate market participation. Second, unlike other studies, the research has considered the macroeconomic news announcements and market sentiment factors to explore a clear connection between the price discovery mechanism of currency spot and futures markets of USD/INR. To our knowledge, this is the first study to explore the price discovery and volatility spillover effects of spot and futures market prices for the two intervals, i.e. pre-COVID and COVID periods. Moreover, the study employed an asymmetric Multivariate GARCH model to examine the existence of volatility persistence and asymmetric effects and to discriminate the effects of positive and negative news for both sample periods.

In regard to this, the study is organized as follows: Section 2 provides the literature review. Section 3 describes the data and methodology. Section 4 outlines the results and discussion, and the final section concludes the paper.

1. LITERATURE REVIEW

1.1 The theoretical framework

Efficient market theory postulates that all available information is promptly incorporated into asset prices. Thus, any new information arrivals in the market should be reflected simultaneously in both spot and futures prices. This situation results in perfect positive contemporaneous comovement between the two markets, eliminating arbitrage opportunities. Accordingly, the Cost of Carry (COC) futures pricing model postulates that.

$$F_t = S_t\, e^{(r-y)\,(T-t)} \qquad (1)$$

where Ft is the futures price at time t, St is the spot price at time t, r is the interest rate foregone while carrying the underlying asset, y is the dividend yield and T − t is the remaining life of the futures contract. A no-arbitrage assumption justifies equation (1) since $F_t > S_t e^{(r-y)\,(T-t)}$ would enable investors to profit by selling futures and buying stocks. $S_t e^{(r-y)\,(T-t)} > Ft$ would allow profits by buying futures and short-selling stocks. The underlying assumptions are that both the futures and spot markets operate with perfect efficiency and that transaction costs are nonexistent. This simplified model also assumes that interest rates and dividend yields remain constant throughout the futures contract. However, market frictions—such as transaction costs, margin requirements, short-sale constraints, differences in liquidity, and non-synchronous trading—can create a lead-lag relationship between the futures contracts and their underlying spot markets. Therefore, the price discovery mechanism revolves around whether new information reflects changes in futures or spot prices. The dissemination of information establishes a lead-lag relationship between the spot and futures markets.

The futures market leads the spot market due to its advantages, including higher liquidity, lower transaction costs, lower margins, ease leverage positions, rapid execution and greater flexibility for short positions. Such advantages attract informed traders and make the futures market more responsive to market-wide or major firm-specific information. Thus, futures prices will lead to spot market prices. Moreover, the benefits in the futures market will attract larger speculative traders from a spot market and reduce informational asymmetries. This results in better price discovery by lowering the noise trading and improving the market depth, efficiency, and liquidity. This makes the spot market react first when market-wide information or major information arrives. Besides, there is a possibility for the bidirectional causality between futures and spot prices, with spot to futures market prices or vice versa, signifying that both spot and futures markets respond simultaneously to new information.

1.2 Empirical literature review

Prior studies have documented the dominance of futures markets in the price discovery mechanism, highlighting that futures prices often lead to spot prices across various currency pairs. Hong (2010) found that futures markets lead spot markets for several currencies, including the British Pound, Australian Dollar, Canadian Dollar, Brazilian Real, and Won/Dollar, with a robust effect of currency futures on spot markets. Sehgal et al. (2015) and Kharbanda and Singh (2017) showed that futures prices tend to precede the movements in the spot prices in the short run for currencies, viz. British Pound, Euro, US Dollar, and Japanese Yen against the Indian Rupee. The GARCH-BEKK model results confirmed short-term volatility transmission from futures to spot prices, with longer-term volatility transmission from spot to futures markets. Sharma and Chotia (2019) demonstrated unidirectional causality from futures to spot markets for currencies, including the Euro, British pound and Yen against the Indian rupee, reinforcing the role of futures in price discovery. Koilada and Sk (2019) found that futures prices lead the spot prices for USD/INR, GBP/INR, and EUR/INR, whereas for JPY/INR, the spot market led the futures market. Kaur et al. (2020) confirmed that futures markets lead spot markets for GBP/INR and EUR/INR, with bidirectional causality observed in the case of JPY/INR, supporting the idea that futures markets are crucial in the process of price discovery for some currencies. Devan et al. (2022) found that spot price is led by future price, thus contributing substantially to the price-discovery process in the Indian Foreign Exchange Market.

In contrast, the authors have found evidence that spot markets lead futures markets, indicating that spot prices contribute more prominently to the price discovery process for certain currencies. For example, Sharma (2011) suggested that the spot market influences the futures market for USD/INR, providing further support for the lead of spot markets in some cases. Raghavendra and Velmurugan (2013) found that the spot market influences the futures market in GBP/INR, suggesting that the spot market plays a leading role in price discovery. Sriram and Senthil (2013) showed a one-way causality and volatility flowing from the spot market to futures prices for GBP/INR and JPY/INR. Chen et al. (2016) studied price discovery between spot and futures rates for the EUR–USD and JPY–USD markets and found that the spot rates provide more price discovery than the futures rate. Saktivel et al. (2017) provided evidence of one-way causality and volatility transfer from the spot to the futures market for GBP/INR, JPY/INR, and EUR/INR.

Some studies indicate a bidirectional relationship between spot and futures markets, where both markets simultaneously influence each other, while others report mixed evidence regarding the direction of price discovery. For instance, Unlu and Ersoy (2012) found a two-way causal relationship between the futures and spot markets in Turkish currency markets. This indicates a complex dynamic where both markets influence each other in the short and long term. Boyrie et al. (2012) identified mixed evidence in the price discovery process for the South African Rand, Brazilian Real and Russian Ruble. They found that futures markets lead the spot market for the Brazilian Real, while for the Russian Ruble, the spot market is the leading market, and the South African Rand showed mixed evidence. Ivanov et al. (2013) suggested that the spot market significantly contributes to price discovery but also highlighted the complex relationships between spot, futures, and exchange-traded funds (ETFs), showing that both markets influence each other. Martinez and Tse (2017) established bidirectional causality in the USD-MXN market, with the spot market partially leading the futures market. This suggests that both markets have a role in price discovery. Raju and Manohar (2018) used cointegration and causality tests to examine the price discovery mechanism for EUR/INR, USD/INR, GBP/INR, and YEN/INR. Their findings showed bidirectional causality for USD/INR and GBP/INR, while futures markets lead the spot market for YEN/INR and EUR/INR. Nath and Pacheco (2018) observed a two-way volatility spillover between the USD/INR spot and the currency futures market. Kumar (2018) demonstrated that the spot market consistently leads the futures market for the Indian rupee and South African rand, while the futures market leads the spot market for the Brazilian real.

It is evident from existing research that the price discovery function in emerging markets is well-documented. However, the studies related to the Indian currency market are meagre. Moreover, the question of which market price is the pioneer in price discovery and volatility spillover remains unresolved, especially in the Indian context. The inter-connectedness between the futures and spot markets is intertwined with other macroeconomic factors and market sentiments. Furthermore, the relationship is time-varying and behaves differently at various time intervals and crisis periods. Therefore, considering the macroeconomic news announcements and market sentiment factors, the study aims to explore the price discovery and volatility spillover between currency spot and futures market prices for the two intervals, i.e., pre-COVID and COVID periods. Accordingly, the research proposes the following hypotheses:

H1: Futures markets serve as an effective price discovery instrument, which supports the hypothesis that futures prices lead to spot prices (futures prices contain helpful information about the underlying spot market).

H2: Spot markets serve as an effective price discovery instrument, which supports the hypothesis that spot prices lead to futures prices (spot prices contain helpful information about the futures spot market).

H3: Bidirectional causality exists between the two-price series, and spot and futures are important in price discovery.

2. METHODOLOGY

2.1 Data

The study uses minute-wise data of spot and futures prices of USD/INR traded on the National Stock Exchange (NSE), India. The time-series data is classified into two sub-periods: the pre-COVID-19 Phase (1st August 2019 to 24th January 2020) and the COVID-19 Phase (25th January 2020 to 31st August 2020). This paper used macroeconomic news announcements and futures and spot market sentiment indices as the control variables to examine price discovery and volatility spillover effect. Following Wang (2004) and Safa and Maroney (2012), the sentiment index is related to the open interest (measures the liquidity) and trading activity of the futures market. Hence, we compute the volume-based sentiment index for the futures market (VBSI_F) based on the natural logarithm of the ratio of open interest to the traded volume of the futures market. Similarly, the market sentiment index for the spot market (VBSI_S) is computed by taking the natural logarithm of the open interest ratio to the spot market's traded volume. A ratio of more than one implies substantial trading pressure, whereas less than one suggests negligible trading pressure. A ratio of one signifies that the trading pressure in the respective market is balanced. The macroeconomic schedule announcements on Gross Domestic Product (GDP), Fiscal Policy, Inflation, RBI Policy Rates and Trade Deficit are collected from the Bloomberg database. The tick-by-tick data on the currency spot and futures markets are retrieved from Accelpix Solutions Pvt. Ltd., the NSE Authorised Vendor in Equity, Index, Futures and Options.

2.2 Model Specification

2.2.1 Autoregressive Distributed Lag Model (ARDL)

The ARDL technique proposed by Pesaran et al. (2001) takes the following form:

$$\Delta \ln SP_t=\alpha_o+\sum_{i=1}^{n}\alpha_1\Delta \ln SP_{t-1}+\sum_{i=1}^{n}\alpha_2\Delta \ln FP_{t-1}+\beta_1 \ln SP_{t-1}+\beta_2 \ln FP_{t-1}+\beta_3 \ln VBSI\_F_{t-1}$$
$$+\gamma_1 D_1+\gamma_2 D_2+\gamma_3 D_3+\gamma_4 D_4+\gamma_5 D_5+\varepsilon_{1t} \quad (2)$$

$$\Delta \ln FP_t=\alpha_o+\sum_{i=1}^{n}\alpha_1\Delta \ln FP_{t-1}+\sum_{i=1}^{n}\alpha_2\Delta \ln SP_{t-1}+\beta_1 \ln FP_{t-1}+\beta_2 \ln SP_{t-1}+\beta_3 \ln VBSI\_S_{t-1}$$
$$+\gamma_1 D_1+\gamma_2 D_2+\gamma_3 D_3+\gamma_4 D_4+\gamma_5 D_5+\varepsilon_{1t} \quad (3)$$

where ln is the natural log and Δ is the first difference operator. As stated in Pesaran and Pesaran (1999), the F-statistic is employed to test the presence of a long-run relationship under the hypothesis. γDsare dummy variables included accounting for macroeconomic news announcements viz. Fiscal Policy(D_1), Gross Domestic Product (D_2), Inflation (D_3), RBI Policy Rates (D_4) and Trade Deficit (D_5). It takes the value 'one' on announcement days. Otherwise, it is 'zero'.

The *ARDL* specification of the error correction model is formulated as follows:

$$\Delta \ln SP_t=\alpha_o+\textstyle\sum_{i=1}^{n}\alpha_1\Delta \ln SP_{t-1}+\sum_{i=1}^{n}\alpha_2\Delta \ln FP_{t-1}+\beta_1 \ln VBSI\_F_{t-1}$$
$$+\gamma_1 D_1+\gamma_2 D_2+\gamma_3 D_3+\gamma_4 D_4+\gamma_5 D_5+\delta_1 Z_{t-1}+\varepsilon_{1t} \quad (4)$$

$$\Delta \ln FP_t=\alpha_o+\textstyle\sum_{i=1}^{n}\alpha_1\Delta \ln FP_{t-1}+\sum_{i=1}^{n}\alpha_2\Delta \ln SP_{t-1}+\beta_1 \ln VBSI\_S_{t-1}$$
$$+\gamma_1 D_1+\gamma_2 D_2+\gamma_3 D_3+\gamma_4 D_4+\gamma_5 D_5+\delta_1 Z_{t-1}+\varepsilon_{2t} \quad (5)$$

Where $\delta_1$is the error correction term, *a*s are the short-run parameters.

2.2.2 Volatility persistence and Asymmetric volatility test

We tested for ARCH and GARCH effects in the returns series by employing univariate GARCH models. The GARCH (1,1) process is *in the following form:*

$$h_t=\alpha_0+\sum_{i=1}^{q}\alpha_i u_{t-i}^2+\sum_{i=1}^{p}\beta_i h_{t-i} \quad (6)$$

where h_t is the conditional variance. α_1 and β_1 represent ARCH and GARCH effects, respectively, suppose the sum of $\alpha_1+\beta_1$ is close to unity. In that case, any shock will permanently change all future values of conditional variance, i.e., a shock to the conditional variance is persistent. It takes a long time to die out. Moreover, we employed the sign and size bias tests Engle and Ng (1993) proposed to evaluate the effect of volatility changes due to a negative or positive return shock. The squared residual term is regressed against a dummy variable that reflects the sign of the residual term. Using ε_{it}, *i = spot price (SP), futures price (FP)* to indicate the residual of asset *i* at time *t*; we conduct each test by ordinary least squares (OLS) estimates (7) – (10):

Sign bias test: $\varepsilon_{i\,t}^2 = a + b_1 SP_{i\,t-1}^{-} + u_{it}$ (7)

Negative size bias test: $\varepsilon_{i\,t}^2 = a + b_2 SP_{i\,t-1}^{-}\varepsilon_{i\,t-1} + u_{it}$ (8)

Positive size bias test: $\varepsilon_{i\,t}^2 = a + b_3 SP_{i\,t-1}^{+}\varepsilon_{i\,t-1} + u_{it}$ (9)

Joint bias test: $\varepsilon_{i\,t}^2 = a + b_1 SP_{i\,t-1}^{-} + b_2 SP_{i\,t-1}^{-}\varepsilon_{i\,t-1} + b_3 SP_{i\,t-1}^{+}\varepsilon_{i\,t-1} + u_{it}$ (10)

2.2.3 The Multivariate GARCH Model

The Multivariate Asymmetric GARCH (Diagonal VECH) is employed to examine the volatility transmission across the markets. Suppose there are more than two variables in the conditional variance-covariance matrix. In that case, the model permits the conditional variance-covariance matrix of market returns to change over time and offers maximum flexibility than the Baba, Engle, Kraft, and Kroner (BEKK) model (Scherrer and Ribarits, 2007). In matrix notation, the dimensions of the conditional variance-covariance matrix (H_t) are shown by equation (11):

$$\begin{bmatrix} h_{ss,t} \\ h_{sf,t} \\ h_{ff,t} \end{bmatrix} = \begin{bmatrix} c_{ss,t} \\ c_{sf,t} \\ c_{ff,t} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t-1}^2 \\ \varepsilon_{s,t-1}, \varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}^2 \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \begin{bmatrix} h_{ss,t-1} \\ h_{sf,t-1} \\ h_{ff,t-1} \end{bmatrix} \quad (11)$$

where h_{ss}, h_{ff} are the conditional variance of the errors $(\varepsilon_{st}, \varepsilon_{ft})$ from the mean equations. As the model has numerous parameters to be estimated, Bollerslev et al. (1988) proposed a restricted version of the above model with α and β matrixes and diagonal elements, which allow for a time-varying conditional variance. The diagonal representation of the conditional variance elements "h" _"ss" and "h" _"ff" and the covariance element "h" _"sf" takes the following forms and are shown in equations (12) – (14):

$$h_{ss,t} = c_{ss} + \alpha_{11}\varepsilon_{s,t-1}^2 + \beta_{11} h_{ss,t-1} \quad (12)$$
$$h_{sf,t} = c_{sf} + \alpha_{22}\varepsilon_{s,t-1}\varepsilon_{f,t-1} + \beta_{22} h_{sf,t-1} \quad (13)$$
$$h_{ff,t} = c_{ff} + \alpha_{33}\varepsilon_{ft-1}^2 + \beta_{33} h_{ff,t-1} \quad (14)$$

where h_s is a conditional variance at time t of spot market return, and h_f is at the time t of futures market return. h_{sf} denotes the conditional covariance between the spot and futures market returns at time t.

The diagonal VECH model can be written as follows:

$$VECH(H_t)=C+AVECH\left(\varepsilon_{t-1}\varepsilon_{t-1}^{1}\right)+BVECH(H_{t-1}) \quad (15)$$

Where A and B are $\frac{N(N+1)}{2}$ x $\frac{N(N+1)}{2}$ parameter matrices and C is $a\ \frac{N(N+1)}{2}x1$ vector of constants. The diagonal elements of matrix A (a_{11}, a_{22}, a_{33}, a_{44}) capture the effect of own-volatility shocks while non-diagonal elements (a_{ij} where $i \neq j$), measure the cross-volatility shocks. The diagonal elements of matrix B (b_{11}, b_{22}, b_{33}, b_{44}) measure the own-volatility spillovers, and non-diagonal elements (b_{ij} where $i \neq j$) measure the cross-volatility spillovers. The study included a threshold term in the variance-covariance equation to capture the asymmetric volatility spillover. The model used in this study is expressed as:

$$VECH(H_t)=C+A.VECH(\epsilon_{\downarrow t-1}(t-1)\epsilon_{\downarrow t-1}(t-1)^{\uparrow})+B.VECH(H_{t-1})+D.VECH\left(\epsilon_{\downarrow t-1}(t-1)\epsilon_{\downarrow t-1}(t-1)<0\right)*$$

$$\left(\left(\epsilon_{\downarrow t-1}(t-1)\epsilon_{\downarrow t-1}(t-1)^{\uparrow'}\right)<0\right)'D^{*}VECH\left(\epsilon_{\downarrow t-1}(t-1)\epsilon_{\downarrow t-1}(t-1)^{\uparrow'}\right)<0^{*}\left(\epsilon_{\downarrow t-1}(t-1)\epsilon_{\downarrow t-1}(t-1)^{\uparrow'}\right) \quad (16)$$

where, *A, B and C* are $\frac{N(N+1)}{2}$ x $\frac{N(N+1)}{2}$ parameter matrices and C is a $\frac{N(N+1)}{2}$ vector of constant. a_{ij}in matrix A, i.e., diagonal elements indicate their innovation effect, and the cross-diagonal terms (a_{ij}, $i \neq j$) indicate the cross-innovation effect. Besides, b_{ii} in matrix B indicates its volatility effect, and b_{ii} represents the cross-volatility effect. d_{ii} measures the asymmetry volatility spillover effect from the i^{th} market to itself. d_{ii} shows the asymmetric volatility spillover effect from the i^{th} market to the j^{th} market.

3. RESULTS AND DISCUSSION

3.1 Price discovery in the currency futures market

Figures 1 and 2 show the time-series plot of currency spot and futures prices of the United States dollar/Indian rupee (USD/INR) for the pre-COVID and COVID phases. It is observed that the price movements during the COVID period rose more than those in the pre-COVID Phase. Both markets had a high degree of comovement, which would aid portfolio managers in diversifying their portfolios and risk managers in hedging them through an effective price discovery mechanism.

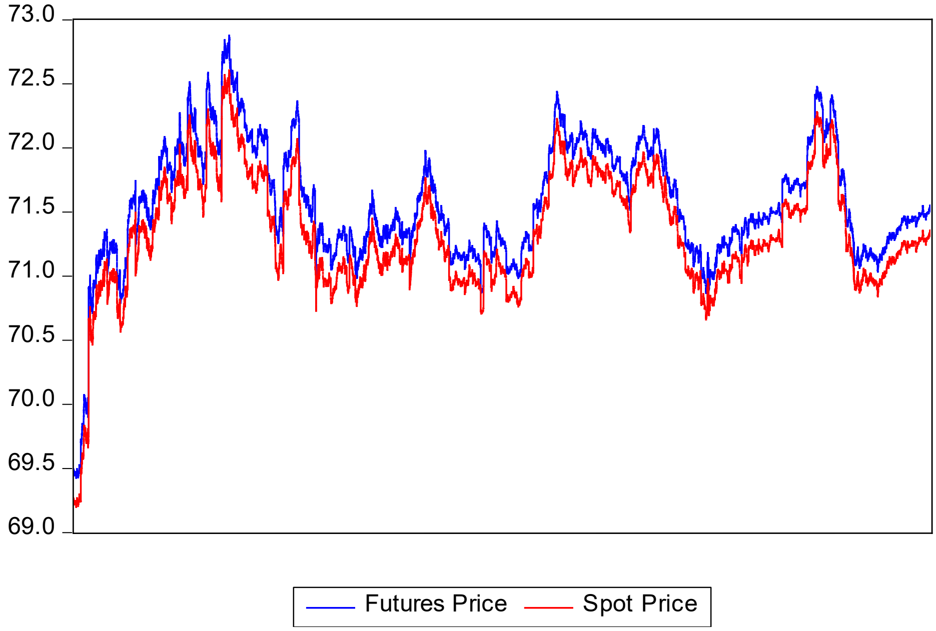

Figure 1. Time-series plot of currency spot and futures prices
Source: Own

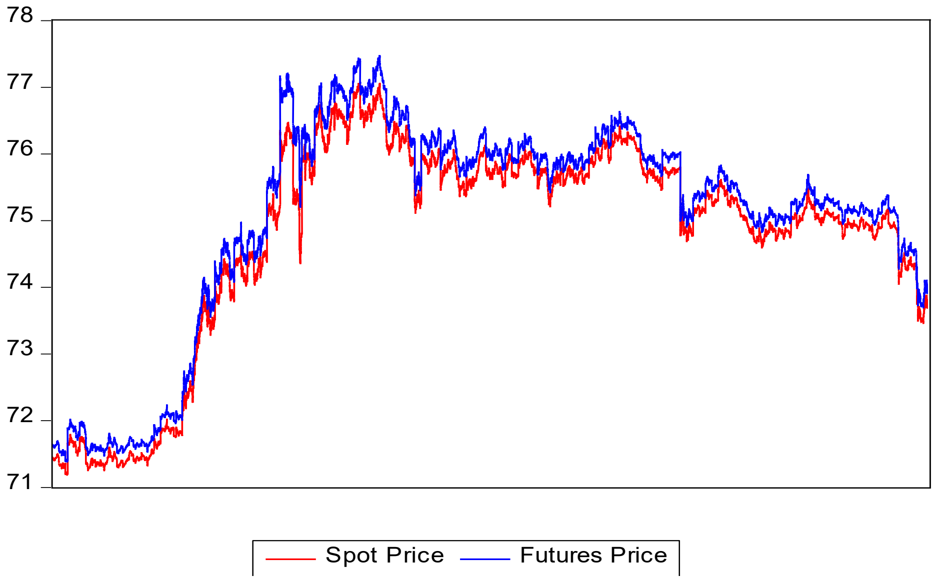

Figure 2. Time-series plot of currency spot and futures prices
Source: Own

Table 1 reports the descriptive statistics of the returns, trading volume, and volume-based sentiment index of currency spot and futures markets of USD/INR for the pre-COVID and COVID phases. The mean returns and standard deviations during both phases are close to zero, and the non-zero skewness value indicates that both returns are positively skewed. Higher kurtosis values indicate that both the return series are fat-tailed. Moreover, the Jarque-Bera test rejects the null hypothesis of normally distributed returns. The average volume-based sentiment index of spot and futures markets of USD/INR for both sample periods is greater than one, suggesting sufficient trading pressure and positive sentiments.

Table 1. Descriptive statistics

	Spot Return	Futures Return	VBSI_S	VBSI_F
Pre-COVID-19 Phase				
Mean	0.0000155	0.0000152	1.924483	2.677370
Std. deviation	0.0000414	0.0000419	0.314621	1.822498

Skewness	13.41945	13.10628	4.959627	5.919033
Kurtosis	1047.171	1017.536	111.0577	47.22541
J-B statistics	2.05E+09* (0.0000)	1.93E+09* (0.0000)	22117101* (0.0000)	3937037* (0.0000)
Observations	45080	45080	45080	45080
COVID-19 Phase				
Mean	0.0000116	0.0000118	1.869480	2.662546
Std. deviation	0.0000504	0.0000505	0.243183	1.753425
Skewness	6.886236	9.941547	1.457228	6.199197
Kurtosis	1281.301	1633.290	9.131034	51.63977
J-B test	3.81E+09* (0.0000)	6.20E+09* (0.0000)	107497.8* (0.0000)	5877265* (0.0000)
Observations	55984	55984	55984	55984

Source: own

First, the order of integration of the variable of interest is examined by employing the Kwiatkowski–Phillips–Schmidt–Shin test *(KPSS)* test, and the results are shown in Table 2. The results for the pre-COVID Phase show that spot and futures market returns series are stationary at levels. The volume-based sentiment index series of spot and futures markets are stationary at their first differences. The COVID phase results show that spot and futures market returns and volume-based sentiment index series of spot market series are stationary at levels. The futures markets' volume-based sentiment index series are stationary at first difference. This indicated that the series was integrated at various levels during the pre-COVID and COVID phases. Thus, the Autoregressive Distributed Lag *(ARDL)* bounds test approach is appropriate for analysing the long-run association between the underlying variables.

Table 2. KPSS unit root test results

Variables	Level	First Difference	Order of Integration
Pre-COVID-19 Phase			
Spot Return	0.2345*	--	I(0)
Futures Return	0.2384*	--	I(0)
VBSI_S	3.6377	0.0057*	I(1)
VBSI_F	1.6782	0.0229*	I(1)
COVID-19 Phase			
Spot Return	0.5133*	--	I(0)
Futures Return	0.5424*	--	I(0)
VBSI_S	0.1484*	--	I(0)
VBSI_F	5.3464	0.0811*	I(1)

Source: own
Note: * shows significance at 1% level. Critical values for the KPSS statistic are 0.7390, 0.4630, and 0.3470 at the 1%, 5%, and 10% significance levels, respectively.

As shown in Table 3, the F-statistics are greater than the upper bound critical value at a 1% significance level, indicating a stable long-run equilibrium relationship between currency spot and futures market prices of USD/INR. Therefore, the markets are weak-form inefficient, and there are arbitrage opportunities.

Table 3. ARDL bounds test for cointegration

Pre-COVID-19 Phase		
Specification		F-Statistics
SP /FP, VBSI_F, $D_{1Fiscal\_rates}$, D_{2GDP}, $D_{3Inflation}$, D_{4RBI}, $D_{5Trade\_deficit}$		9.5010*
FP /SP, VBSI_S, $D_{1Fiscal\_rates}$, D_{2GDP}, $D_{3Inflation}$, D_{4RBI}, $D_{5Trade\_deficit}$		9.0984*
Significance level	Lower bound	Upper bound
10%	3.02	3.51
5%	3.62	4.16
2.5%	4.18	4.79
1%	4.94	5.58
COVID-19 Phase		

Specification		F-Statistics
SP/FP, $VBSI\_F$, $D_{1Fiscal\_rates}$, D_{2GDP}, $D_{3Inflation}$, D_{4RBI}, $D_{5Trade\_deficit}$		7.3547*
FP/SP, $VBSI\_S$, $D_{1Fiscal\_rates}$, D_{2GDP}, $D_{3Inflation}$, D_{4RBI}, $D_{5Trade\_deficit}$		7.0493*
Significance level	Lower bound	Upper bound
10%	3.02	3.51
5%	3.62	4.16
2.5%	4.18	4.79
1%	4.94	5.58

Source: own
Note: An asterisk (*) indicates statistical significance at the 1% level.

The cointegration analysis enables us to apply an error correction model to examine the lead-lag relationship between currency futures and spot prices for both sample periods. Panel A and B in Table 4 depict the results of the causality test based on the ARDL-ECM approach for the pre-COVID and COVID phases, respectively. The empirical evidence from the pre-COVID-19 Phase (Panel A) reveals that the error correction coefficients of spot and futures prices are negative and statistically significant at a one percent level, implying that a long-term equilibrium relationship binds both markets. The lagged coefficients of changes in futures prices in the spot equation are positive and significant, indicating that the futures market leads the spot market. Consequently, the futures equation's lagged changes in spot prices are positive and statistically significant, implying that the spot market leads to the futures market. Notably, the magnitude of changes in spot prices is relatively greater than in futures prices. Hence, the currency spot market of USD/INR contains valuable information about futures prices and plays a price discovery role. Spot market prices are informationally more efficient than futures market prices during the pre-COVID-19 Phase. Moreover, the negative and significant effect of VBSI on futures market returns suggests that investors' sentiment in the currency spot market reduces futures market return due to increased interest in the spot market. The macroeconomic announcements on fiscal policy and trade deficit significantly influenced the currency spot market returns. Besides, fiscal policy announcements, trade deficits, and inflation-related news significantly affected futures market returns during the pre-COVID-19 Phase.

Table 4. ARDL-ECM estimates

Panel A: Pre-COVID-19 Phase			
Selected Model: ARDL (4, 4)			
Dependent Variable: $\Delta(lnSP_t)$		Dependent Variable: $\Delta(lnFP_t)$	
Variables	Coefficient	Variables	Coefficient
$\Delta(lnSP_{t-1})$	-0.677192* (0.004647)	$\Delta(lnFP_{t-1})$	-0.684620* (0.004619)
$\Delta(lnSP_{t-2})$	-0.437511* (0.005247)	$\Delta(lnFP_{t-2})$	-0.437820* (0.005232)
$\Delta(lnSP_{t-3})$	-0.216326* (0.004617)	$\Delta(lnFP_{t-3})$	-0.217576* (0.004583)
$\Delta(lnFP_t)$	0.956135* (0.001240)	$\Delta(lnSP_t)$	0.972158* (0.001261)
$\Delta(lnFP_{t-1})$	0.670801* (0.004607)	$\Delta(lnSP_{t-1})$	0.690603* (0.004661)
$\Delta(lnFP_{t-2})$	0.430171* (0.005195)	$\Delta(lnSP_{t-2})$	0.445251* (0.005283)
$\Delta(lnFP_{t-3})$	0.213592* (0.004548)	$\Delta(lnSP_{t-3})$	0.220532* (0.004653)
$VBSI\_F$	4.58E-08 (6.80E-08)	$VBSI\_S$	-3.63E-07* (1.32E-07)
$D_{1Fiscal\_policy}$	5.27E-05** (2.33E-05)	$D_{1Fiscal\_policy}$	-4.89E-05** (2.35E-05)
D_{2GDP}	1.26E-05 (2.69E-05)	D_{2GDP}	-2.14E-05 (2.71E-05)
$D_{3Inflation}$	1.74E-05 (1.48E-05)	$D_{3Inflation}$	-3.64E-05** (1.49E-05)
D_{4RBI}	1.93E-06	D_{4RBI}	-1.23E-06

	(3.30E-05)		(3.32E-05)
$D_{5Trade\_deficit}$	3.81E-05** (1.91E-05)	$D_{5Trade\_deficit}$	3.62E-05*** (1.92E-05)
Z_{t-1}	-0.002853* (0.000534)	Z_{t-1}	-0.002836* (0.000543)
Panel B: COVID-19 Phase			
Selected Model: ARDL (4, 4)			
Dependent Variable: $\Delta(lnSP_t)$		Dependent Variable: $\Delta(lnFP_t)$	
Variables	Coefficient	Variables	Coefficient
$\Delta(lnSP_{t-1})$	-0.255031* (0.004124)	$\Delta(lnFP_{t-1})$	-0.264256* (0.004129)
$\Delta(lnSP_{t-2})$	-0.074851* (0.004243)	$\Delta(lnFP_{t-2})$	-0.074343* (0.004256)
$\Delta(lnSP_{t-3})$	-0.034440* (0.004117)	$\Delta(lnFP_{t-3})$	-0.039316* (0.004120)
$\Delta(lnFP_t)$	0.918804* (0.001569)	$\Delta(lnSP_t)$	0.935443* (0.001594)
$\Delta(lnFP_{t-1})$	0.251748* (0.004119)	$\Delta(lnSP_{t-1})$	0.266112* (0.004136)
$\Delta(lnFP_{t-2})$	0.070650* (0.004234)	$\Delta(lnSP_{t-2})$	0.078137* (0.004266)
$\Delta(lnFP_{t-3})$	0.035559* (0.004139)	$\Delta(lnSP_{t-3})$	0.037383* (0.004099)
VBSI_F	2.37E-07** (1.17E-07)	*VBSI_S*	-1.56E-06* (3.98E-07)
$D_{1Fiscal\_policy}$	4.83E-05 (3.60E-05)	$D_{1Fiscal\_policy}$	2.30E-05 (3.63E-05)
D_{2GDP}	-0.000506* (5.71E-05)	D_{2GDP}	0.000195* (5.75E-05)
$D_{3Inflation}$	-2.44E-05 (2.34E-05)	$D_{3Inflation}$	1.49E-05 (2.35E-05)
D_{4RBI}	0.001977* (3.61E-05)	D_{4RBI}	-0.001718* (3.66E-05)
$D_{5Trade\_deficit}$	-4.89E-05** (2.44E-05)	$D_{5Trade\_deficit}$	-3.65E-05 (2.46E-05)
Z_{t-1}	-0.001158* (0.000246)	Z_{t-1}	-0.001083* (0.000235)

Source: own
Note: Significance levels are marked by *, **, and *, corresponding to 1%, 5%, and 10%, respectively.

Panel B results for the COVID-19 Phase indicate that the error correction coefficients of spot and futures prices are negative and statistically significant, confirming the long-run relationship between the markets. The lagged coefficient of spot and futures returns are statistically significant, implying the bidirectional causation between the two markets. The magnitude of changes in spot prices is relatively greater than in futures prices. Hence, the currency spot market of USD/INR contains valuable information about futures prices and plays a price discovery role during COVID-19. The sentiment index significantly impacted spot and futures market returns during the COVID-19 pandemic. Further, macroeconomic announcements related to GDP, RBI policy rates, and trade deficits had significant responses to the currency spot market. The GDP and RBI policy rate announcements significantly influenced futures market returns.

3.2 Volatility persistence, Asymmetric response, and spillover effect

Before analyzing the volatility spillover between spot and futures markets for both sample periods, we tested for ARCH and GARCH effects in the return series using univariate GARCH models. The results in Table 5 indicate that both the currency spot and futures returns of USD/INR show time-varying persistence in their conditional variances.

Table 5. Univariate GARCH model estimates

	Spot Market Return	Futures Market Return
Pre-COVID-19 Phase		
c	-1.13E-06* (4.18E-08)	-8.14E-07* (3.16E-08)
r_{t-1}	0.061712* (0.0011)	0.014902* (0.0008)
$\alpha_i u_{t-i}^2$	0.812680* (0.0021)	0.812624* (0.0022)
$\beta_i h_{t-i}$	0.104066* (0.0011)	0.101560* (0.0010)
COVID-19 Phase		
c	-5.19E-06* (4.33E-08)	-4.53E-06* (1.29E-08)
r_{t-1}	-0.207404* (0.0015)	-0.098784* (0.0003)
$\alpha_i u_{t-i}^2$	0.982148* (0.0025)	0.984210* (0.0014)
$\beta_i h_{t-i}$	0.006548* (0.0001)	0.006888* (0.0004)

Source: own

Note: Values in () represent probability levels. * indicate significance at the 1%.

Following Park et al. (2020), the study examines the volatilities of the spot and futures markets asymmetry using the sign and size bias tests proposed by Engle and Ng (1993). Table 6 depicts the bias test results for the spot and futures market returns residuals. The findings indicate that the spot and futures markets demonstrate asymmetric volatility, suggesting that the USD/INR exchange rate is more sensitive to negative than positive news during the pre-COVID period. Besides, the volatility of both markets is more sensitive to positive shocks during the COVID phase. This suggests that investors feel optimistic due to confidence in vaccination efforts, the easing of lockdown restrictions, and government and central bank stimulus measures worldwide. As a result, they are reacting strongly to positive news, which has led to increased market volatility.

Table 6. Bias test results

	Spot market return	Futures market return
Pre-COVID-19 Phase		
Sign bias test	1.79E-10 (0.7352)	3.36E-10 (0.5306)
Negative size bias test	-2.94E-05* (0.0062)	-1.83E-05*** (0.0870)
Positive size bias test	3.53E-06 (0.6783)	6.78E-06 (0.4259)
Joint bias test	2.733** (0.0421)	1.389 (0.2439)
COVID-19 Phase		
Sign bias test	-2.42E-09* (0.0017)	-1.83E-09** (0.0360)
Negative size bias test	3.40E-06 (0.7764)	--5.10E-06 (0.7104)
Positive size bias test	2.59E-05** (0.0156)	2.63E-05** (0.0290)
Joint bias test	4.088* (0.0065)	2.624** (0.0487)

Source: own

Note: significance levels denoted by *, **, and *** at 1%, 5%, and 10%, respectively.

The volatilities of USD/INR spot and futures market returns demonstrate ARCH and GARCH effects with asymmetrical characteristics. To examine the volatility spillover between these markets, we utilized a Multivariate GARCH model. Furthermore, we estimated the time-varying conditional variance-covariance of the spot and futures market returns using the diagonal VECH model for both sample periods, as illustrated in Figures 3 and 4. These figures suggest that the Multivariate GARCH-type model is well-suited for analyzing the spillover effects of the return series.

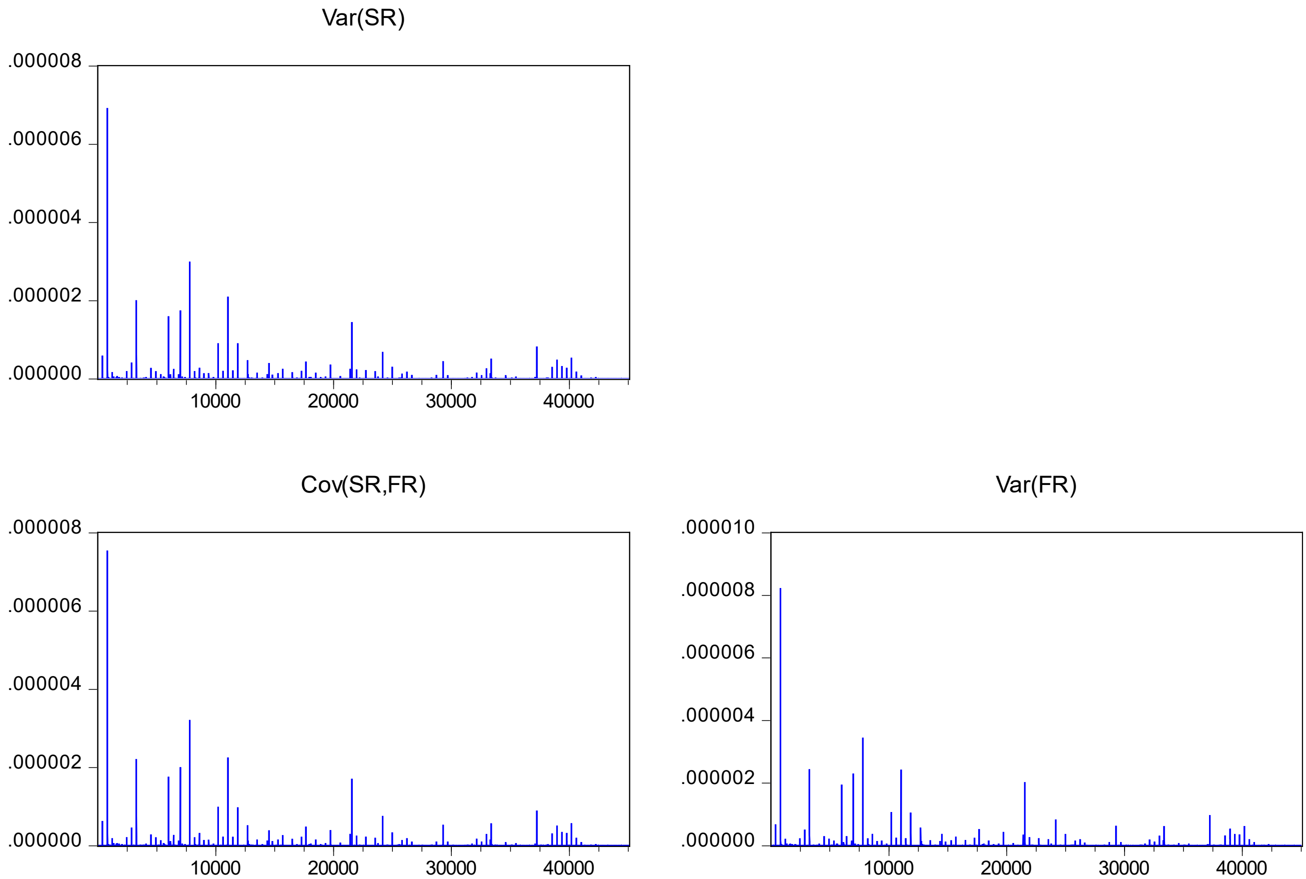

Figure 3. Conditional Variance-Covariance for the Pre-COVID-19 Phase
Source: own

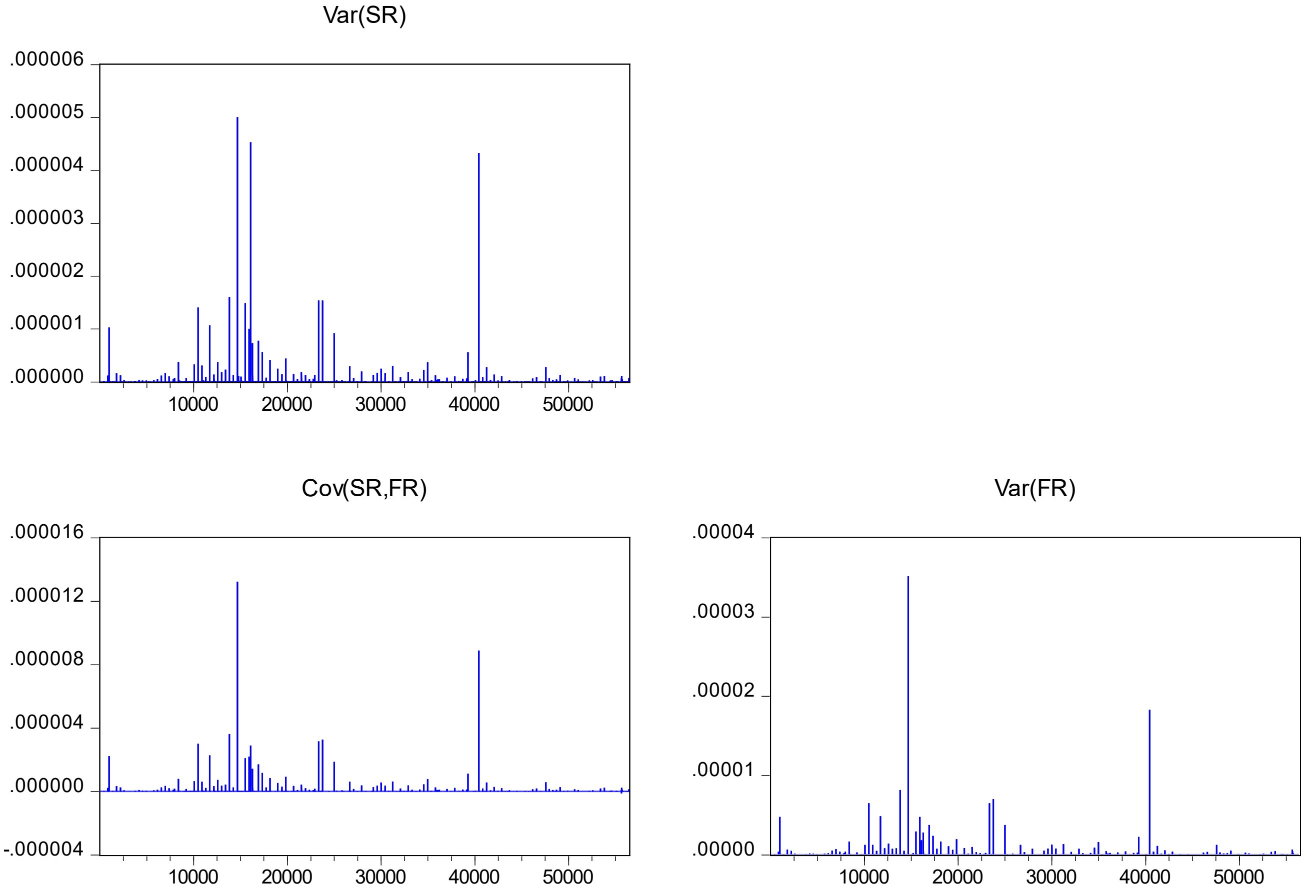

Figure 4. Conditional Variance-Covariance for the COVID-19 Phase
Source: own

The evidence in Table 7 indicates that the diagonal parameters ($A_{1,1}$ and $B_{1,1}$) are positive and statistically significant in both sample periods. This suggests a strong ARCH and GARCH (1,1) process, which confirms that past shocks and volatility influence volatility in both the spot and futures markets. The cross-market volatility spillover coefficients in matrices A ($A_{1,2}$ and $A_{2,1}$) and B ($B_{1,2}$ and $B_{2,1}$) are statistically significant at one percent level, indicating bidirectional volatility spillovers between the spot and futures markets during the pre-and COVID phase. The unidirectional linkage from the spot to futures markets is more pronounced, where shocks are transmitted from the spot markets to the futures markets for USD/INR. Furthermore, the asymmetric coefficients found in matrix D ($D_{1,1}$, $D_{1,2}$ and $D_{2,1}$) are statistically insignificant, indicating no asymmetric response in the volatility of the spot and futures markets to positive or negative shocks during both sample periods.

Table 7. Parameters estimates of asymmetric diagonal VECH model

Pre-COVID-19 Phase				COVID-19 Phase		
Panel A: Conditional mean						
Variable	Co-efficient	Std. error	Prob. value	Co-efficient	Std. error	Prob. value
Dependent Variable: spot market return						
c	-8.12E-07	-8.12E-07	0.1356	-2.10E-05	8.07E-07	0.0000
r_{st-1}	-0.0421	-0.0421	0.0000	-0.2443	0.0036	0.0000
r_{ft-1}	0.1134	0.1134	0.0000	0.1509	0.0030	0.0000
$VBSI\_F_{t-1}$	-1.05E-09	-1.05E-09	0.9885	5.60E-09	8.12E-08	0.9450
$VBSI\_S_{t-1}$	-5.61E-08	-5.61E-08	0.8546	9.26E-06	4.61E-07	0.0000
Dependent Variable: futures market return						

c	-9.59E-07	5.33E-07	0.0718	-1.87E-05	5.20E-07	0.0000
r_{st-1}	0.4415	0.0040	0.0000	0.2894	0.0026	0.0000
r_{ft-1}	-0.3430	0.0041	0.0000	-0.4012	0.0029	0.0000
$VBSI\_F_{t-1}$	1.97E-08	6.78E-08	0.7718	1.24E-08	5.21E-08	0.8122
$VBSI\_S_{t-1}$	-9.73E-09	2.92E-07	0.9734	8.15E-06	3.04E-07	0.0000
Panel B: Conditional variance						
$C_{1,1}$	7.38E-10	1.12E-12	0.0000	1.61E-09	7.28E-12	0.0000
$C_{1,2}$	6.73E-10	7.34E-13	0.0000	1.42E-09	3.40E-12	0.0000
$C_{2,2}$	6.51E-10	1.19E-12	0.0000	1.27E-09	2.28E-12	0.0000
$A_{1,1}$	0.7584	0.0037	0.0000	0.4254	0.0030	0.0000
$A_{1,2}$	0.8209	0.0030	0.0000	0.8736	0.0058	0.0000
$A_{2,1}$	0.8907	0.0035	0.0000	0.9808	0.0128	0.0000
$D_{1,1}$	1.11E-06	0.0084	0.9999	3.38E-06	0.0079	0.9997
$D_{1,2}$	4.86E-07	0.0077	0.9999	-3.40E-08	0.0130	0.9995
$D_{2,1}$	1.11E-06	0.0080	0.9999	1.02E-06	0.0260	0.9994
$B_{1,1}$	0.3160	0.0007	0.0000	0.2049	0.0033	0.0000
$B_{1,2}$	0.3426	0.0001	0.0000	0.1994	0.0017	0.0000
$B_{2,1}$	0.3708	0.0008	0.0000	0.2154	0.0011	0.0000
LB	9.7986 (0.549)			9.8715 (0.627)		
LB^2	0.0766 (0.782)			0.0817 (0.960)		

Source: own

Note: Matrix A represents both the within-market and cross-market ARCH effects, whereas Matrix B accounts for the corresponding GARCH effects. Matrix D is designed to capture asymmetric impacts. The Ljung-Box statistics for the standardized residuals and their squares are denoted by LB and LB2, respectively.

The parameter estimates provided similar evidence for both sample periods. The Ljung-Box statistics for standardized and standardized squared residuals indicated no autocorrelation or heteroskedasticity, suggesting that the estimated Multivariate GARCH models are stable.

CONCLUSION

Price discovery and spillover effect are essential indicators for arbitrageurs and hedgers in the currency futures market to protect their interests from price swings. The lead-lag relationship between currency futures and spot markets is analysed through the ARDL approach for the pre-and COVID-19 Phase. The cointegration test results confirm the long-run association between the futures and spot market for INR/USD. The ARDL-based error correction model result highlights a bidirectional relationship between both markets, with a greater lead for the spot market. This result confirms that spot prices dominate price discovery in the currency market during both sample periods. Moreover, the study results reveal that the volatility spillover occurs from the spot to the futures market for both sample periods. There is no significant evidence of asymmetric behaviour of the currency spot and futures market returns.

The study reveals no difference in the outcome of the price discovery mechanism and a volatility spillover effect in the currency market between the pre-and COVID pandemic periods. It suggests a more substantial flow of information from the spot market to the futures market, highlighting the role of the spot market in price discovery and volatility spillover. From a policy perspective, this study provides valuable insights for investors and policymakers, helping them navigate and regulate the market effectively, especially in future pandemics. The findings could aid portfolio management, market structure design, arbitrage, and hedging practices. Regulators, such as the Securities and Exchange Board of India (SEBI) and the Reserve Bank of India (RBI), should pay close attention to the relationship between currency spot and futures markets. They should monitor the volatility transmission between these markets, particularly during pandemic outbreaks.

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