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Research Article

Intraday Price Discovery between Spot and Futures Markets of NIFTY 50: An Empirical Study during the Times of COVID-19

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The current study investigates the intraday dynamics of futures and spot markets in India. By analyzing one-minute data of Nifty 50 and the associated futures index, the study finds that both the markets are cointegrated. The results of the VECM reveal that any disequilibrium between the spot and futures market is restored by the spot market. Granger causality tests reveal that the spot and futures markets have a bidirectional causal relationship. Common factor weights and Hasbrouck's information share (IS) reveal the greater role of the futures market in price discovery. Gonzalo and Granger's common factor model indicates that the permanent factor is made up of futures series only. Using the BEK-GARCH model, we found two-way volatility spillovers between the spot and futures markets. The futures market is found to have a greater impact in terms of volatility spillovers also. The findings of our research are relevant to investors, money managers, traders, and policymakers.

1. Introduction

One of the major constituents of the derivatives market is the futures market. Futures markets' two primary roles are price discovery and risk management [1]. These two reasons have sparked a lot of research on the link between these two markets [2, 3]. A vibrant futures market also helps improve the efficiency of the underlying spot market [4]. The importance of the index futures market has been studied extensively in developed countries, with the majority of studies focusing on the United States [5]. Firstly, spot-futures relation was investigated in the context of cointegration or associated error correction [6–11]. Secondly, the lead-lag relationship was investigated between the spot index market and index futures market. The index futures market is mostly found to lead the spot index market and plays the leading role in price discovery in most developed countries [8, 9, 12]. Some studies also reported a bidirectional relationship between spot and futures markets [13, 14]. It is noteworthy that even if the link between the spot and futures market is bidirectional, the link from futures to spot markets is stronger [6, 7, 9, 12, 15–20].

While the dominant role of the futures market is reported from the developed markets, the evidence from the emerging markets is mixed [21]. Chiang and Fong [22] reported that the Hang Seng index futures dominate the spot index returns. Zhong et al. [23] showed that the stock index futures market of Mexico had a leading role in the price discovery [24]. They contend that the futures markets have a smaller advantage over the spot markets in other countries than they do in the United States [13, 25, 26].

The evidence regarding the price discovery is very interesting in India. While Debasish [27] and Pati and Rajib [28] report the leading role of the futures market, Pradhan and Bhat [29] and Sehgal et al. [30] provide evidence in favor of the leading roles of the spot market [31]. Furthermore, a bidirectional feedback relationship between the spot and futures indices of the Nifty 50 is found by Mukherjee and Mishra [32] and Atif and Naseem [33]. Recently, Karmakar and Inani [14] reported that before 2014, the spot market was the leading market, but after 2014, the futures market has assumed the leading role.

The mixed results from the Indian market call for further investigation regarding the spot-futures relationship [34]. The case of India is important for several reasons. First, India is the largest democracy in the world and is among the fastest-growing economies. In the last few years, the Indian financial markets specially the derivatives markets have made remarkable progress. The Indian derivatives market stands at number one globally in terms of the number of contracts traded [35, 36]. One more reason for studying the spot-futures relation is the change in the relative roles of the individual and institutional investors in India. During the COVID-19 pandemic, the retail participation of the investors surged dramatically worldwide [36–38]. According to a report released by the NSE in October 2021, the unique trading accounts of investors are more than 50 million. Of these 50 million investors, 40% have been added during the pandemic. Given the increased importance of the individual investors, it becomes imperative to examine the spot-futures relationship. In this backdrop, the present study makes several contributions [39]. First, only a few studies have employed high-frequency data in the Indian market and getting an insight into the lead-lag relation high-frequency intraday data is needed. To fill this gap, we employ data at the frequency of 1 minute. Second, the present study will uncover whether the spot-futures relation has changed in the light of the enhanced role of retail investors. Third, the sample period covers one of the greatest catastrophes of all times, i.e., COVID-19.

Using 1-minute data from January 1, 2020, to December 31, 2020, we find that there is a long-run relationship (cointegration) between the spot and futures indices of the Nifty 50. The results of the Granger causality test for returns show a bidirectional causality between the futures and spot markets [40]. However, the size of the statistics indicates a greater impact of futures on the spot market. Various price discovery measures also reveal a greater role of the futures market. The Granger causality test results reveal bidirectional volatility spillovers between the spot and futures markets. The BEKK-GARCH (1,1) model also indicates the bidirectional volatility spillovers between the spot and futures markets. The rest of the study is organized as follows. Section 2 reviews the relevant literature followed by data and methodology in Sections 3 and 4. The empirical findings are presented in Section 5, and the final observations are presented in Section 6.

2. Review of Existing Literature

This section goes over the following reliable research on the derivatives market, including its size and the relationship between the spot and futures markets in emerging economies such as India and China and the developed markets around the world.

Amongst the studies conducted in the developed markets, Stoll and Whaley [12] explored the price discovery among the spot index and futures markets of the MM and S&P 500 index. The ARMA (p,< >q) model was applied to the intraday data from 1982 to 1987 and they traded on the CBOT. The futures market was found to lead the spot market by approximately 5 minutes. In another study, Chan [9] investigated the cash index and index futures market returns of the S&P 500 and MMI for price discovery using the intraday data. The two markets were found to have asymmetric lead-lag relationships with futures dominating the spot index. Tse [8] studied the Nikkei stock index and its associated index futures for price discovery. He utilized the ECM, ARIMA, and VAR methods and found futures contract was leading in the price discovery. In another study, Wallace et al. [41] explored the price discovery between the S&P 500 E-mini futures and SPY ETF from 2002 to 2013. The study used the information leadership share (ILS) metric of Putnins [42] and found that the E-mini futures led ETF up to the sample period of 2007. The results revealed that both the futures and ETF had taken part in almost the same proportion in the price discovery process after 2007. Alemany et al. [43] analyzed the 5 min intraday data collected for the period between January 2014 and September 2015 to study how arbitrage opportunity played a role in the lead-lag relationships of DAX30 futures and the underlying index. They used the Markov switching VECM model to capture the nonlinear dynamics of the long-run relationship and regime-dependent impulse response function for dynamic interaction between the variables and disturbance terms [44]. The futures market was found to lead the spot market when there were more arbitrage opportunities in the markets.

The spot-futures relation has also been studied in the emerging markets. Atilgan et al. [45] did a detailed review of the literature for the 25 emerging countries including India and China. They found that the futures markets lead the spot markets. Hou and Li [46] examined the CSI 300 stock index futures and the underlying market of China, for the intraday price discovery. A 5-minute interval data was analyzed from 1st March to 31st March 2011 using the cointegration test and VECM. The futures market was discovered to have a prominent role in the price discovery process. Also, Judge and Reancharoen [47] studied the spot and futures markets of Thailand for lead-lag relationships from 2006 to 2012 by applying VECM on daily data. The results revealed the futures market leading the spot market amid the market imperfections [48]. Moreover, using a 5-minute intraday data between January 2013 and October 2013, Zhou and Wu [49] explored the linkages between China's CSI 300 futures and cash indexes. They applied the VAR-DCC-MGARCH model and found the two-way causal relationships between the two markets. However, Wang et al. [50] analyzed the CSI 300 index futures and spot market's intraday, and daily price dynamics from 2010 to 2014 by applying the optimal path method. The daily data revealed that the futures and spot markets had no lead-lag relation, while the intraday data reported that the cash market was led by the futures market by 5 minutes. In another study conducted by Hao et al. [13], three index futures and their underlying indices of the Chinese stock market for price discovery using 5 min intraday data were analyzed. They applied the VECM, the Granger causality test, the common factor weights (CFW), and Hasbrouck's information share (IS) approach and found that the cash market led the futures market before the stock exchange regulation in 2015. They reported that the futures market dominated after regulation [51]. Guo [52] studied the CSI 300 index futures and the underlying index to analyze the lead-lag linkages using a 5 min interval of intraday data from October 2013 to June 2016. They employed the VECM approach and found the spot market to be strongly led by the futures market before and up to the boom period in June 2015 [53]. After that, the futures weakly led the spot market.

In India, Karmakar and Inani [14] studied "35 single stocks, and their futures from NSE, India, for price discovery." They also analyzed the S&P CNX Nifty spot and futures for price discovery. They utilized 1 min frequency data from January 2012 to December 2016. They used common share, information share, and MIS models in panel data analysis. The findings revealed the dominance of the spot market over other markets in price discovery up to 2014, and after that, the futures market led all. Roy and Chakraborty [54] examined the equity stock futures and underlying stocks on NSE, India, by collecting the daily closing prices of 10 stocks and the closing prices of the futures of these stocks from January 2011 to January 2017. They found long-run linkages between the equity stock futures and spot markets. The study further reported that in the short run, spot market led the futures market, but in the long run, both markets contributed equally to the price discovery.

On the basis of the review of the existing literature, it can be concluded that in the developed and emerging markets, the futures markets led the spot markets. In India, only a few studies have examined the relationship using high-frequency data. Therefore, a recent study using high-frequency data is needed to uncover the spot-futures dynamics in the light of the developments in the Indian market.

3. Data Description

The current study has 93756 observations at the frequency of one minute for the spot and futures indices of NIFTY 50 in India from January 1, 2020, to December 31, 2020. Table 1 provides summary statistics of one min returns for both markets. Since the first return on each day represents an overnight return, the first return is omitted to avoid any negative impact on data analysis [55, 56].

Descriptive statistics presented in Table 1 show that the spot and futures markets' one-minute percentage returns are close to zero. The mean return for the spot is negative, i.e., −0.0000128 percent, whereas the mean return for the futures is positive, i.e., 0.000255 percent. As can be seen from the table, the value of standard deviation for the spot index returns is 0.061432 percent, while 0.065302 percent standard deviation was observed for futures returns. All the return series are skewed in the positive direction. The values of Kurtosis indicate that Nifty 50 futures returns are more leptokurtic.

Table 1: Summary statistics for one minute log returns for the spot and futures markets.

	RSPOT	RFUT
Mean	$-1.28E-05$	0.000255
Median	0	−0.00021
Maximum	4.562856	6.236863
Minimum	−1.74247	−1.55749
Std. Dev.	0.061432	0.065302
Skewness	4.554105	9.421988
Kurtosis	368.2	928.3452
Jarque-Bera	$5.21E+08$	$3.35E+09$
Probability	0	0
Observations	93756	93756

Table 2: Karl Pearson's correlation.

	RSPOT	RFUT
RSPOT	1	0.939212
RFUT	0.939212	1

Source: author's calculation.

3.1. Correlation Analysis. A correlation analysis is performed to determine the degree of association between Nifty 50 spot and futures returns. Table 2 displays the outcomes of Karl Pearson's correlation coefficient.

The correlation coefficient as given in Table 2 between the spot and futures markets indicates that they are both substantially positively correlated, implying that they have a short-term relationship.

Figure 1 depicts the intraday spot and futures price movements across the sample period. During the sample period, it appears that the spot prices have a similar movement as is observed in the futures prices. In the next section, we use cointegration analysis to study this more formally.

4. Methodology

4.1. Augmented Dickey–Fuller Test. Before investigating the numerous links between the spot and futures markets, it is imperative to investigate the presence of a unit root in the underlying time series. The augmented Dickey and Fuller [57] test for unit root nonstationarity is applied for this purpose.

4.2. Cointegration Analysis. The cointegration test [58] is used to investigate the long-term relationships between two or more variables. Cointegration is used to investigate the long-run association of nonstationary time series. Two or more nonstationary time series are called cointegrated if their linear combination is stationary. Theory suggests that spot and futures prices should be cointegrated because of the cost it carries. Therefore, a linear combination of spot and futures prices should make a stationary series. The given

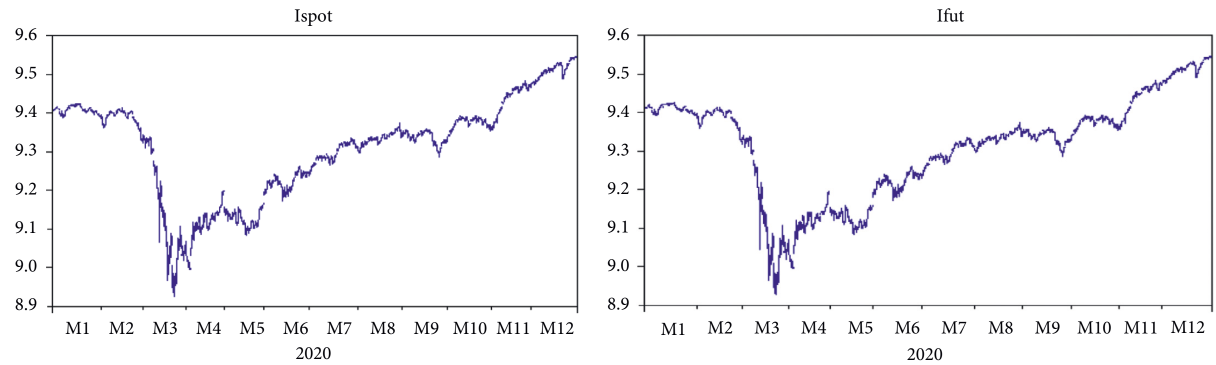

Figure 1: 1 min time plot of spot and futures log prices. Source: authors' creation.

equation represents a stationary linear combination of the two-time series:

$$u_t = S_t - \alpha - \beta F_t, \quad (1)$$

where $(-1, \beta)$ is the cointegrating vector, and u_t is a stationary disturbance term that occurs as a result of a mean-reverting process. We can rewrite equation (1) as

$$S_t = \alpha + \beta F_t + u_t. \quad (2)$$

Further, the appropriate modeling strategy for cointegrated variables is the vector error correction model. The nth-order bivariate VECM can be built as follows:

$$\Delta Y_t = \phi + \Pi Y_{t-1} + \sum_{i=1}^{n-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t, \quad (3)$$

where

$$\begin{aligned} Y_t &= (S_t, F_t); \\ \Delta Y_t &= (\Delta S_t, \Delta F_t). \end{aligned} \quad (4)$$

Δ denotes the first-difference operator which is used for calculation of return from prices, i.e., $\Delta S_t = S_t - S_{t-1}$;$\phi$ is a constant term; $\Pi = \gamma\beta'$ is used as a coefficient matrix, where $\gamma = (a_s, a_f)$ and $\beta^1 = (1 - \beta)$;Γ_i is a (2×2) coefficient matrix where $\Gamma_i = \begin{pmatrix} a_{s,i} & b_{s,i} & a_{f,i} & b_{f,i} \end{pmatrix}$.

Finally, $\varepsilon_t = (\varepsilon_{s,t}, \varepsilon_{f,t})$ is a vector containing the error terms of the two markets which are independent and identically distributed. Equation (3) can be expanded as

$$\begin{aligned} \Delta S_t &= a_{s,0} + a_s u_{t-1} + \sum_{i=1}^{n-1} a_{s,i} \Delta S_{t-i} + \sum_{i=1}^{n-1} b_{s,i} \Delta F_{t-i} + \varepsilon_{s,t}, \\ \Delta F_t &= a_{f,0} + a_f u_{t-1} + \sum_{i=1}^{n-1} a_{f,i} \Delta S_{t-i} + \sum_{i=1}^{n-1} b_{f,i} \Delta F_{t-i} + \varepsilon_{f,t}. \end{aligned} \quad (5)$$

"Error correction term (ECT) is used for examining the long-run equilibrium relationship" of the two-time series (S_t and F_t), denoted by $u_{t-1} = S_{t-1} - \alpha - \beta F_{t-1}$, and the adjustment speed is measured by γ.

Cointegration among the variables in the system is investigated with the help of the trace statistic, found in the rank of the matrix Π [59].

The VECM is used for investigating the short- and long-run effect of the price changes between the two variables Engle and Granger [60]. It studies the deviation of prices from the equilibrium. The ECT coefficients a_s and a_f, measure the long-run adjustment speed to the equilibrium. The sign of the correction error coefficient term is determined by the two opposing effects [23].

The coefficients $a_{s,i}, b_{s,i}, a_{f,i}$, and $b_{f,i}$ are used to determine the short-run effects of the lagged values of one variable on the current value of other variables. $a_{f,i}$ determines the short-run effect of spot returns on the futures returns, and $b_{s,i}$ measures the short-run effects of the futures return on spot returns. Moreover, $a_{s,i}$ and $b_{f,i}$ measure the own lagged short-run effect of spot and futures markets.

Firstly, in order to find long-run relationships, the error correction coefficients are tested. We can find a feedback effect between the futures and spot returns in the long run if null hypotheses $a_f = 0$ and $a_s = 0$ are rejected. However, if only one null hypothesis is rejected, then one market leads/lags the other market in the long run [20, 61].

Secondly, in order to formally examine the spot-futures price lead-lag relationship, the Granger causality test is utilized. Causality should really exist in at least one direction if futures and spot markets are cointegrated [62]. If spot-to-futures causality is one-directional (St Granger causes Ft), some information contents must be there in the past spot prices to predict the futures prices of the futures market.

To examine the price discovery roles of the spot and futures markets, we employ three different measures. The first measure proposed by Schwarz and Szakmary [63] provides common factor weights (CFW) and is based on the coefficients of the error correction terms in the VECM. The CFW for spot and futures markets is simple and intuitive and is given as follows:

$$\begin{aligned} \text{CFW (spot)} &= \frac{|\alpha_f|}{|\alpha_s| + |\alpha_f|}, \\ \text{CFW (futures)} &= \frac{|\alpha_s|}{|\alpha_s| + |\alpha_f|}, \end{aligned} \quad (6)$$

where α_s and α_f are the coefficients of the error correction terms in the spot and futures equation, respectively.

The second measure of the price discovery employed by us is the information share of Hasbrouck [2] which is based on the permanent-transitory decomposition of the model. Hasbrouck's approach is based on the determination of the implicit efficient price which is common but unobservable for all markets. Hasbrouck [2] defines the information share of a particular market as the contribution of a market's innovation to the innovation of the common efficient prices.

The third measure of the price discovery used by us is because of Gonzalo and Granger [64]. The approach of Gonzalo and Granger [64] is also based on the common factor representation proposed by Stock and Watson [65]. Gonzalo and Granger [64] suggest that the common factor can be obtained in terms of the linear combination of the data series under consideration. The advantage of Gonzalo and Granger's [64] approach over the Stock and Watson's approach[65] is that in the former case, it is easy to test the hypothesis about the contribution to a common factor.

Similar to the return linkages between the spot-futures markets, volatility linkages are equally important. In this study, we investigate the volatility linkages using the Granger causality test described above. We also investigate the volatility linkages using the bivariate GARCH. The study employs the bivariate GARCH proposed by Baba, Engle, Kraft, and Kroner (BEKK). The reason for choosing BEKK over the other GARCH-family models is that in BEKK, covariances are allowed to be influenced by the lagged variances [66]. Furthermore, BEKK has fewer parameters as compared to other specifications. The BEKK specification is given as follows:

$$\begin{aligned} R_t &= \phi_0 + \varepsilon_t, \\ \varepsilon_t | \omega_{(t-1)} &\sim N(0, H_t), \\ H_t &= C'C + A' \varepsilon_{t-1} \varepsilon_{t-1}^{'} A + G' H_{t-1} G. \end{aligned} \tag{7}$$

The H_t matrix can be written in the expanded form as follows:

$$\begin{aligned} h_{ss,t} &= c_{ss}^2 + a_{ss}^2 \varepsilon_{s,t-1}^2 + 2a_{ss} a_{fs} \varepsilon_{s,t-1} \varepsilon_{f,t-1} + a_{fs}^2 \varepsilon_{f,t-1}^2 \\ &\quad + g_{ss}^2 h_{ss,t-1} + 2g_{ss} g_{fs} h_{sf,t-1} + g_{fs}^2 h_{ff,t-1}, \\ h_{sf,t} &= h_{fs,t} = c_{ss} c_{fs} + a_{ss} a_{sf} \varepsilon_{s,t-1}^2 \\ &\quad + \left(a_{fs} a_{sf} + a_{ss} a_{ff}\right) \varepsilon_{s,t-1} \varepsilon_{f2,t-1} + a_{fs} a_{ff} \varepsilon_{f,t-1}^2 \\ &\quad + g_{ss} g_{sf} h_{ss,t-1} + \left(g_{fs} g_{sf} + g_{ss} g_{ff}\right) h_{sf,t-1} \\ &\quad + g_{fs} g_{ff} h_{ff,t-1}, \\ h_{ff,t} &= c_{fs}^2 + c_{ff}^2 + a_{sf}^2 \varepsilon_{s,t-1}^2 + 2a_{sf} a_{ff} \varepsilon_{s,t-1} \varepsilon_{f,t-1} \\ &\quad + a_{ff}^2 \varepsilon_{f,t-1}^2 + g_{sf}^2 h_{ss,t-1} + 2g_{sf} g_{ff} h_{sf,t-1} \\ &\quad + g_{ff}^2 h_{ff,t-1}. \end{aligned} \tag{8}$$

$R_t = \left[R_{s,t} \;\; R_{f,t} \right]^{'}$ is a vector of the futures and spots' returns; $\varepsilon_t = \left[\varepsilon_{s,t} \;\; \varepsilon_{f,t} \right]^{'}$ is a Gaussian error vector. $\varnothing_0$ is a constant vector. C is a lower triangular matrix of the intercept coefficients, and H_t stands for conditional variance-covariance matrix. The square matrix "A" components evaluate the effect of shocks or "news" on conditional variances. In conditional volatility, the G matrix describes the degree to which volatility persists. The matrix A's diagonal parameter measures the effects of the previous shocks, i.e., the ARCH effect and the matrix G's diagonal parameter calculates its own GARCH effect. The shock and volatility cross-market impacts are measured by the matrices A and G's off-diagonal components.

5. Empirical Results

Table 3 shows the outcomes of the ADF tests; it can be concluded that the log prices of both the markets have a unit root at 5 percent significance level, i.e., both the price series are I. On the basis of the outcomes of the ADF test on the first difference, it can be concluded that both series' returns (first difference) are stationary, and none of the two series is I.

5.1. Granger Causality Test. To examine the short-run linkages, we used the Granger causality test based on the VAR described as follows:

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \sum_{i=1}^{p} \beta_i \Delta X_{t-i} + \epsilon_t \ldots. \tag{9}$$

Table 4 highlights that there is a two-way causality between the spot and futures markets at a 5 percent level of significance. However, if we consider the size of the test statistic, then it appears that the futures market has a greater impact on the spot market.

Table 5 displays the outcomes of the cointegration test between the two markets. The trace statistic and the max-eigen test indicate only one cointegrating vector at a 5-percent significance level. Therefore, it can be concluded that Nifty futures and the underlying spot index have a long-run relationship.

Table 6 shows the estimates of the VECM. From the table, it can be seen that the error correction term (a_s) is significant at a 1% level. This implies that the spot market reacts to restore the equilibrium in the long run.

Table 7 presents the estimates of price discovery measures. IS, lower bound, and IS, upper bound, represent the Hasbrouck [2] information share of the two markets. It is clear that the information of the spot market can range from 0.3% to 90.5% while the information share of the futures market can range from 9.5% to 99.7%. The average information share for the spot and futures markets is 45.4% and 54.6%, respectively. Clearly, the futures market has more contribution toward the price discovery. If we look at the common factor weight (CFW), then we see that the relative share of the spot and futures market in price discovery is 15.2% and 84.8%, respectively. In addition, we employ the Gonzalo and Granger [64] approach to test the null hypothesis that the entire price discovery takes place in the futures market. The test produced a chi-squared statistic of 0.4846 with a p-value of 0.4864 at 1 degree of freedom. This further consolidates the price discovery role of the futures market.

Table 3: unit root test.

Variables	At level		At first difference	
	t-stats	Probability	t-stats	Probability
Spot	−0.625695	0.8626	133.1946	0.0001
Futures	−0.679822	0.85	131.4618	0.0001

Source: author's calculation.

Table 4: Granger causality test.

Null hypothesis	Obs.	F-stats	Probability
R_SPOT => R_FUT	93751	8.85042	$2.00E-08^{*}$
R_FUT => R_SPOT		208.664	$4.00E-222^{*}$

Source: author's calculation. *Note.** denotes significance at 5% level; => implies "does not Granger cause."

Table 5: The Johansen cointegration test.

Hypothesised No. of CE(s)	Trace-stats	Probability	Max-eigen stats	Probability
At none*	142.5607	0.0001*	142.2016	0.0001*
At most 1	0.359168	0.549	0.359168	0.549

Source: author's calculation. *Note.** indicates 5% significance level.

Table 6: Estimates of the vector error correction model.

Cointegrating equation	Coint. equation (1)	
LSPOT(−1)	1	
LFUT(−1)	−0.9929***	
	−0.0013	
	[−742.788]	
C	−0.0662	
Error correction:	D(LSPOT)	D(LFUT)
CointEq1	−0.0054***	−0.0009
(a_s, a_f)	0.0015	0.0015
	[−3.6671]	[−0.6319]
D(LSPOT(−1))	−0.1771***	0.0341***
(a_{si}) (a_{fi})	0.0128	0.0132
	[−13.8863]	[2.5905]
D(LSPOT(−2))	−0.0834***	−0.0439***
(a_{si}) (a_{fi})	0.0130	0.0134
	[−6.4024]	[−3.2678]
D(LFUT(−1))	0.2278***	$-1.36E-05$
(b_{si}) (b_{fi})	0.0124	0.0128
	[18.419]	[−0.0011]
D(LFUT(−2))	0.0714***	0.0248
(b_{si}) (b_{fi})	0.0127	0.0131
	[5.6246]	[1.8913]

Source: author's calculation. Note: ***indicates 1% level of significance.

Table 7: Price discovery measures

Measure	Spot	Futures
IS: lower bound	0.003	0.095
IS: upper bound	0.905	0.997
CFW	0.152	0.848

Table 8: Test of Granger causality between the market volatilities of the spot and futures indices.

Null hypothesis	Obs.	F-stats	Probability
FUT_GARCH => SPOT_GARCH	93751	175.208	0.0000*
SPOT_GARCH => FUT_GARCH		131.711	0.0000*

Source: author's calculation. *Note.** indicates significance at 5 percent level; and => implies " does not Granger cause."

Table 9: Estimates of the BEKK-GARCH(1,1).

Parameter	Estimate	p value
c_{ss}	0.0023	0.0000***
c_{fs}	0.0016	0.0000***
c_{ff}	0.0012	0.0000***
a_{ss}	0.3125	0.0000***
a_{sf}	0.0595	0.0000***
c_{fs}	−0.1221	0.0000***
a_{ff}	0.1336	0.0000***
g_{ss}	0.9485	0.0000***
g_{sf}	−0.0158	0.0000***
g_{fs}	0.0322	0.0000***
g_{ff}	0.9964	0.0000***

Source: author's calculation. *Note.****indicates significance at 1% level.

5.2. Volatility Linkages. The results of the individual GARCH test reveal that both the selected markets have a GARCH effect which means that the futures value of volatility is affected by the past volatility of market returns. The current study generated a variance series for each market in order to study the volatility linkages, and then the Granger causality was performed. Table 8 summarises the results. Table 8 shows the bidirectional causality of volatility in spot and futures markets.

The BEKK-GARCH bivariate (1, 1) model estimates are shown in Table 9.

The a_{ff} coefficient is statistically significant, implying that the squares of the prior futures market returns shocks have an impact on current futures returns volatility. The statistically significant coefficient a_{ss} denotes that the squares of the prior spot return shocks have an impact on the current spot return volatility. Both the diagonal coefficients a_{fs} and a_{sf} are statistically significant at all conventional levels, showing bidirectional shock transmissions between the spot and futures markets. In addition, g_{sf} and g_{fs} are also statistically significant. This implies that the past conditional volatility of both the series impacts the conditional volatility of the other series. However, if we look at the size of the coefficients, then it can be said that the futures market has more impact on the spot market volatility.

6. Conclusion

The current study investigates the price discovery between the futures and spot markets of India. By analyzing the intraday one-minute data from January 2020 to December 2020, the study finds that both markets have a cointegrating relationship. The results of the VECM reveal that any disequilibrium between the spot and the futures market is restored by the spot market. This indicates that futures market leads the spot market. Granger causality tests reveal that the spot and futures markets have a bidirectional causal relationship. However, the size of the statistics indicates that the futures market has more impact on the spot market. Hasbrouck's information share (IS) and Gonzalo and Granger's common factor models also reveal the price discovery role of the futures market. The bidirectional volatility spillovers among the spot and futures markets are revealed by the Granger causality test on conditional variance series. We also discovered the two-way volatility spillovers among the spot and the futures markets by using the BEKK-GARCH (1, 1) model. The futures market is found to have a greater impact in terms of volatility spillovers also. The findings of our research are relevant to investors, money managers, traders, and policymakers. Our results are in line with the study done by Karmakar and Inani [14]. In the recent times, the relationship between the spot and futures has changed. Earlier it was the spot market which had a greater impact on the futures market [33]. However, the recent data show that it is the futures market which plays a greater role in price discovery. In addition, because the futures volatility tends to surge ahead of spot volatility in the event of a shock, investors who are concerned about the volatility fluctuations might use the futures market's volatility signal to adjust their spot portfolios for risk management. Thus, investors, portfolio managers, and financial analysts should keep an eye on the futures market. Besides, the market regulators should also take appropriate measures to strengthen the futures market as it has a direct impact on the capital market.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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