Hindawi
Discrete Dynamics in Nature and Society
Volume 2022, Article ID 6431403, 14 pages
https://doi.org/10.1155/2022/6431403

Research Article

Does Indian Commodity Futures Markets Exhibit Price Discovery? An Empirical Analysis

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Received 29 November 2021; Revised 31 January 2022; Accepted 3 February 2022; Published 8 March 2022

Academic Editor: Anibal Coronel

Price discovery function analyses the dynamics of futures and spot price behavior in an asset's intertemporal dimensions. The present study examines the price discovery function of the bullion, metal, and energy commodity futures and spot prices through the Granger causality and Johansen–Juselius cointegration tests. The Granger causality test results show bidirectional causality between the spot and futures returns for gold, silver, aluminum, lead, nickel, and zinc. The Johansen cointegration test shows that spot and futures prices are in the long-run equilibrium path for silver, aluminum, lead, nickel, zinc, crude oil, and natural gas. The vector error correction model results suggest that both the spot and futures markets are equally efficient in price discovery for the nickel. The spot market leads the futures market in price discovery for copper and zinc. However, the futures market leads the spot market in price discovery for silver, aluminum, and lead. The findings of the study suggest the market participants for implementing hedging and arbitrage strategies. It also helps the market regulators to examine the stability of these rapidly growing commodity futures markets in India.

1. Introduction

Commodities such as agriculture, metal, and energy are valuable to producers, processors, consumers, lenders, and brokers. Commodities trade on both spot and derivative markets across world commodity derivative markets [1]. Commodity derivative markets include trading of forwards and futures contracts, which derive its values from the market's spot commodities. As a welfare raising mechanism, an efficient commodity futures market plays a vital role in managing price risk uncertainty contextual to the primary commodities [2]. In an open economy, commodity futures markets hold pervasive importance in discovering a reference price for the producers and trade functionaries by reducing price volatility in the commodity prices and uncertain production decisions [3, 4]. Apart from price discovery, Li and Xiong [5] argued that the futures market is a significant instrument for risk management since it provides financial gains such as dissemination of information, and efficient resource allocation. Eventually, the spot price is affected by fundamental factors such as demand and supply, market structure, and government policies. In contrast, the futures price is driven by hedgers, speculators, traders, and other market participants. The study of price behavior in commodity futures markets provides a better analytical perspective towards futures contracts' pricing and on how futures market prices affect the commodities' spot price over time.

Interest in the Indian commodity futures markets is showing an increasing trend over the years. Commodity futures emerges as an attractive investment alternative to the security markets and is also recognized as an increasingly popular vehicle to hedge investments [6]. The existing literature on price discovery and market efficiency in Indian commodity futures markets supports an efficient functioning commodity futures market's economic significance [7–9]. In developed countries, earlier studies emphasized the economic role and function of the commodity futures markets. The researchers' issues drawn considerable attention from the researchers that include intertemporal price behavior, hedging effectiveness, and basis relationship [10, 11].

However, in developing countries, futures markets are subject to higher government control, and reforms are relatively new. There is a gradual shift from an intervention approach to a market-based system in government policies. So, the commodity futures markets' economic role attracted the debate on these markets' economic benefits, such as price discovery and hedging [12]. Given the dynamic, economic, and institutional factors pertinent to the emerging economy, it is evident to expect a significant difference in the dynamics of commodity price behavior in these markets compared to that in a developed economy.

In the context of India, following the reform in the commodity derivative market since 2003, the commodity futures trading for agriculture, metal, and bullion commodities is growing significantly across major commodity exchanges [7, 13, 14]. However, the commodity futures market development's role in minimizing price risk uncertainty and economic efficiency in the spot markets needs to be studied. It is essential to explore the issues that explain the dynamics of Indian commodity futures markets' pricing behavior.

As the futures markets play a significant role in managing price risk and serves the price discovery role for the spot market in the economy, there is a need to look at the dynamics of the futures market's price behavior. In this context, a question arises about how does the futures prices behave?, how to interpret the information it conveys to the market?, and whether futures contracts are effective in reducing price risk? These issues are more pertinent for assessing the performance of the commodity futures market in India. The present study thus attempts to determine the price discovery role of the commodities traded in newly established futures exchanges. Prior studies for India were focused on spot and futures agricultural commodity markets [15–20], gold exchange traded funds [21], metals [22], spot and futures index [23, 24], daily futures, and spot closing prices for various commodities [25–27], both commodities and indices [28]. As compared with earlier literature, the novelty of the current study consists in the fact that three commodity groups are covered, namely, bullion (gold, and silver), metal (aluminum, copper, lead, and zinc), and energy (crude oil and natural gas) over a longer period, respectively, (2006–2018).

The remainder of this paper is organized as follows. Section 2 provides an overview of Indian commodity derivative markets. Section 3 presents the review of earlier literature. Section 4 is focused on empirical techniques. Section 5 exhibits the econometric outcomes. The last section concludes the manuscript and provides policy implications.

2. An Overview of Commodity Derivative Markets in India

The Government of India (GoI) brought various regulations to increase the markets' financialization for multiple commodities. The primary reasons include shifting the price fluctuation risk through hedging and performing the price discovery function and price reference for the spot market [29, 30]. Futures markets serve risk transference and price discovery functions to the economy [31–35]. The presence of speculators facilitates a risk transference function by buying a futures contract from hedgers. The price discovery function implies the use of futures prices on the price formation and transactions in the spot market [31, 33, 36]. So, both price discovery and risk transfer are crucial to justify the futures markets' economic benefit. However, the above features of a futures market are only theoretical. It is necessary to empirically validate these economic functions for evaluating the market performance to meet the objective of an efficient market structure for the commodity market. Alternatively, if futures markets are indeed performing the economic role as mentioned earlier satisfactorily, then there is a strong case for introducing new futures markets for other commodities.

Since the year 1875, commodity futures trading came into existence in India. Still, the market was said to be in hibernation for five decades resulting from strict government control (Kabra, 2007). In the year 2003–04, massive developments took place in the commodity futures market. On April 1, 2003, the government's notification led to the withdrawal of the previous announcements, which restricted futures trading of large quantities in India. Furthermore, a notification came in May 2003, canceling restrictions on nontransferable specific delivery forward contracts. Thus, GoI reduced the restriction in the futures market in expectation of a healthy market institution and efficient market structure. GoI further granted recognition to National Multi-Commodity Exchange of India Limited (NMCEIL), Ahmedabad, in 2002, Multi Commodity Exchange (MCX), Mumbai, and National Commodity and Derivatives Exchange Limited (NCDEX), Mumbai, in the year 2003, followed by Indian Commodity Exchange Limited (ICEXL), Gurgaon, in 2009. The establishment of national-level commodity exchanges resulted in a manifold increase in futures trading. The total turnover of futures trading increased from Rs. 1,294 billion to Rs. 60,070 billion from the year 2003–04 to 2017–18, whereas the total turnover to a gross domestic product increased from 4.6% in 2003–04 to 142.15% in 2017–18 [37, 38]. The developments in commodity futures markets resulted in the exponential growth of the commodity futures segment in the Indian economy. In recent years, commodity futures markets drew attention from the researchers regarding issues such as market efficiency, price discovery, risk management, international linkage, and other matters related to Indian commodity derivative markets [7–9, 14, 39–46].

3. Prior Literature on the Relationship between Futures and Spot Prices

The previous studies [31, 36, 47] emphasized the role of futures markets in price discovery in spot markets. Price discovery also predicts the expected futures spot prices and using the futures prices as a reference price in the spot market. It also helps in finding a reference price for the spot market and helps in identifying the feedback process of information of futures price and spot price. Futures prices shows the expected spot prices [48]. The futures market performs a price discovery function that depends upon the intertemporal relationship between spot and futures prices. Price discovery process reveals us whether futures (spot) market will lead to spot (future) market if all the available information passes on to futures (spot) price and then in spot (future) prices. When all available information is fully and instantaneously utilized in an efficient market to determine the market price, then futures price moves closely with its corresponding price in the spot market with no lag or lead in price movement from one market to another. If there is no difference in each of these markets, then both spot and futures market will react instantly without any lead or lag to the flow of information. Since futures and spot markets represent the same commodity, their prices should exhibit a similar reaction to a given information or event, a process facilitated by arbitrage [49]. A review of previous literature regarding price discovery in commodity futures markets is revealed in Table 1.

A lead-lag relation may exist between the spot and futures markets if one market processes information faster than the other. The factors which affect the lead-lag relationship include ease of short sale, lower transaction cost, institutional arrangement, and market microstructure effect. The lead-lag characteristics of futures and spot markets illustrate how rapidly one market incorporates information relative to others [57]. These characteristics also indicate the efficiency of their functioning and the degree of integration between the two markets [58]. Traders act faster at a lower cost in the futures market than spot market resulting in a lead-lag relation between futures and spot prices [59]. Lin, Chou, and Wang [60] argued that the time-differing lead-lag connection between futures and spot markets is caused, at least to some extent, by the impact of changeable investor confidence. Corredor, Ferrer, and Santamaria [61] revealed that throughout periods of high investor sentiment, the connection between the spot and futures markets diminishes substantially.

Futures trading facilitates the allocation of production and consumption over time by providing market guidance in holding inventories [48]. If the futures price for distant delivery is higher than that for early delivery, the postponement of consumption becomes attractive. Thus, a change in futures price results in a subsequent change in spot prices. Speculators prefer to hold a futures contract because they are not interested in the physical commodity per se, and a futures position can be offset easily. Furthermore, hedgers interested in the physical commodity and have storage constraints may hedge themselves by buying a futures contract. Therefore, both hedgers and speculators may react to information by transacting in futures rather than in the spot market. Consequently, futures price tends to lead the spot price. Chen, Wei, Jin, and Liu [62] found that in the energy futures markets, speculative attitude causes greater market movements than hedging sentiment. In light of the above, the issue of the causal linkage between two markets provides a clear motivation for studying the lead-lag relationship between futures and spot prices.

4. Data and Methodology

The present study used the spot and futures price data from the Bloomberg database. Twenty-one commodity exchanges are operating in India, among them, four exchanges, namely, MCX, NCDEX, NMCEIL, and ICEXL, are national-level commodity exchanges. The rest 17 are regional exchanges in various states to cater to local needs commodity price risk management. According to Futures Industry Association Report [63], MCX is ranked 22nd globally (ranked first among commodity exchanges of India) in terms of total contracts traded in bullion, currency, metal, and energy commodity futures in the year 2019.

Table 2 shows the detailed sample information of the selected commodities for the study. The study used the daily closing futures price of gold, silver, aluminum, copper, lead, nickel, zinc, crude oil, and natural gas traded at MCX. According to Table 3, MCX has the highest share of the total value of trade (from 63.53% to 86.64%) among commodity exchanges in India over the period from 2006 to 2018. Hence, futures prices of various commodity contracts are selected from MCX. The study selected commodities based on each commodity's share in the total trade value in MCX and other exchanges. As well, MCX has the highest percentage of the total value of trade for commodities: gold, silver, aluminum, copper, lead, zinc, crude oil, and natural gas. The total value of traded contracts for these commodities' trade was collected from the Securities and Exchange Board of India (SEBI), the market regulator for the commodity futures market. Metal commodity futures was introduced by the MCX in 2005, whereas bullions were introduced in 2003. One year gap was given in the sampling period to avoid high fluctuation in the dataset.

The futures data include near month series of the daily closing price for the selected commodities. Continuous futures price series data for the selected commodities are collected from the Bloomberg database. Return series is defined as the first difference of natural logarithmic spot price (S_t) and the futures price (F_t) at the level. These are mentioned as follows:

$$\begin{aligned}\Delta S_t &= R_{st} = \ln(S_t) - \ln(S_{t-1}),\\ \Delta F_t &= R_{ft} = \ln(F_t) - \ln(F_{t-1}).\end{aligned} \tag{1}$$

The relationship between spot and futures prices can be explained through the cost-of-carry model and the efficient market hypothesis [64]. If spot price (S_t) and futures price (F_t) series are integrated or I (1), we can estimate the

Table 1: Summary of earlier studies regarding price discovery in commodity futures markets.

Author(s)	Period	Variables	Econometric methods	Empirical outcomes
Indian commodity markets				
Vijayakumar [19]	January 2017–March 2020	Cardamom	Johansen cointegration, vector error correction model, Granger causality, and regression with dummy variables	Cardamom e-auction prices exhibit a negative association with cardamom futures but a positive relation with spot prices
Pradhan, Hall, and Toit [28]	2009–2020	Commodities (aluminum, copper, crude oil, gold, nickel, and silver) and indices (agriculture, livestock, and precious metals)	ARDL bounds testing	Long-run unidirectional causality from spot to futures prices for aluminum, copper, and silver but short-run bidirectional, unidirectional, and neutrality between spot and futures prices
Rout, Das, and Rao [16]	January 2010-December 2015	Chana, chilli, jeera, soya bean, and turmeric.	Causality test, error correction model, EGARCH, and parametric VaR	Volatility spreads from the spot market to the futures market
Nair [22]	January 2008-December 2019	Aluminium, Copper, Nickel, and Zinc	Johansen test, error correction model, and Granger causality	Metals' futures prices are heavily weighted in predicting futures spot market prices
Nair [18]	January 2004–December 2019	Pepper, cardamom, and natural rubber	Cointegration-ECM-GARCH framework	Price discovery in commodity futures markets is efficient
Mohanty and Mishra [17]	October 2015–March 2016	Castor seed, cotton oil cake, rape mustard seed, soybean, refined soya oil, crude palm oil, jeera, chana (chickpea), and turmeric	Variance ratio tests	Agricultural commodity futures markets in India are inefficient in the short term both before and after merger
Manogna and Mishra [15]	2010–2020	Oil seeds (cotton seed, castor seed, soybean seed, rape mustard seed), spices (turmeric, jeera coriander), and grains (guar seed, chana)	Granger causality, vector error correction model (VECM) and exponential generalized autoregressive conditional heteroskedasticity (EGARCH)	Price discovery exists in all of the commodities studied, with the futures market outperforming the spot market in six of them: soybean seed, coriander, turmeric, castor seed, guar seed, and chana
Kaur and Singh [21]	2007–2016	Gold exchange traded funds	Johansen test of cointegration, fully modified ordinary least squares, Toda-Yamamoto test of causality	Spot and futures price movements have been found to lead those of exchange traded funds
Jena, Tiwari, Hammoudeh, and Roubaud [27]	2005–2017	Bullion commodities (gold and silver), and energy commodities (Brent crude oil and natural gas)	Causality-in-quantiles test	Because of its informational efficiency, the foreseeability of the futures market is high in the normal market and declines when the spot market enters severe bearish and bullish situations
Bhaumik, Karanasos, and Kartsaklas [24]	1995–2007	NSE index	Bivariate ARFI-FIGARCH	The integration of futures trading lessens spot variability
Inoue and Hamori [23]	January 2006–March 2011	The spot index (MCXSCOMDEX) and futures index (MCXCOMDEX)	Dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS)	The futures market for commodities appears to be efficient
Joseph, Sisodia, and Tiwari [25]	January 2008–December 2012	Gold, silver, crude oil, natural gas, aluminium, copper, chana, and soybean	Granger causality test and causality analysis in the frequency domain	Almost all of the commodities selected have one-way relationships from futures to spot

Table 1: Continued.

Author(s)	Period	Variables	Econometric methods	Empirical outcomes
Mahalik, Acharya, and Babu [50]	June 2005–December 2008	Agriculture futures price index (LAGRIFP), energy futures price index (LENERGYFP), and aggregate commodity index (LCOMDEXFP)	Vector error correction model (VECM) and bivariate exponential Garch model (EGARCH)	Futures commodity markets exert a leading role and offer effective price discovery in the spot commodity market
Ali and Gupta [20]	2004–2007	Wheat, rice, maize, chickpea, black lentil, red lentil, guar seed, pepper, cashew, castor seed, soybean, and sugar	Johansen cointegration analysis, and Granger causality	Most agricultural commodities exhibit a long-term connection among futures and spot prices
		Worldwide commodity markets		
Jian, Li, and Zhu [51]	April 2015–April 2018	CSI300, SSE50, and CSI500	Skewness-dependent multivariate conditional autoregressive value at risk model (SDMV-CAViaR)	Severe risk overflows in both directions among the Chinese stock index futures and spot markets
Chen and Tongurai [52]	April 2015–March 2020	Copper, aluminium, zinc, lead, nickel, and tin	Forecast error variance decomposition	Chinese futures markets for base metals tend to produce more spillover effects than spot markets
Yu, Ding, Sun, Gao, Jia, Wang, and Guo [53]	July 2003–December 2019	Shanghai metal exchange copper spot prices, COMEX copper futures prices, LME copper futures prices, and Shanghai futures exchange copper futures prices	Wavelet decomposition	The futures markets in New York and London are more associated with the Chinese spot market than the Shanghai futures market
Ausloos, Zhang, and Dhesi [54]	2007–2013	CSI-300 index (China-Shanghai-Shenzhen-300-Stock index) and CSI-300 index futures (CSI-300-IF)	TGARCH, Granger causality, and regression analysis	Two-way Granger causality among futures and spot market in China
Go and Lau [55]	January 2000–July 2016	Crude palm oil spot and futures prices in Malaysian currency	Variance ratio tests	During the bear market time span, spot and futures prices are strongly linked
Kirkulak-Uludag and Lkhamazhapov [56]	2008–2013	Russian spot and three-month futures gold prices	Corrected dynamic conditional correlation model	The conditional correlation among spot and futures gold returns is significantly greater

Source: authors' own work.

Johansen test of multivariate cointegration test [65, 66] for establishing long-run equilibrium and vector error correction model [67] for the direction of short-run causality. This can be expressed as follows:

$$F_t = \beta_0 + \beta_1 S_t + \varepsilon_{ft}, \quad (2)$$

$$S_t = \alpha_0 + \alpha_1 S_t + \varepsilon_{st}, \quad (3)$$

where $S_t = \mathrm{Ln}(S_t)$ and $F_t = \mathrm{Ln}(F_t)$ parameters are represented by α and β, and $\varepsilon_{ft}, \varepsilon_{st}$ represent the deviations from equilibrium relationship between two prices. Johansens's method of cointegration can be explained through vector autoregressive (VAR) representation for (2) and (3).

$$X_t = A_0 X_{t-1} + A_1 X_{t-2} + A_k X_{t-k} + \varepsilon_t, \quad (4)$$

where $X_t = \begin{pmatrix} S_t \\ F_t \end{pmatrix}_{2\times1} [\, S_t \;\; F_t \,]'$ vector represents the natural logarithm of spot and futures price, respectively; $\varepsilon_t = \begin{pmatrix} \varepsilon_{st} \\ \varepsilon_{Ft} \end{pmatrix}_{2\times1}$ is a vector of $[\, \varepsilon_{st} \;\; \varepsilon_{ft} \,]'$ error terms of S_t, F_t, and $\varepsilon_{st}, \varepsilon_{ft} \sim (WN(0, \sigma^2))$; $A_0 = \begin{pmatrix} a_0 \\ a_0 \end{pmatrix}_{2\times1}$ represents a vector of constant, and $A_1 = \begin{pmatrix} a_{1,11} & a_{1,12} \\ a_{1,21} & a_{1,22} \end{pmatrix}_{2\times2}$ represents the parameter matrix. Equation (4) can be transformed into the following forms:

$$\Delta X_t = A_0 + \Pi X_{t-k} + \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-k+1} + \varepsilon_t$$
$$\Delta X_t = A_0 + \Pi X_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-k+1} + \varepsilon_t, \quad (5)$$

where $\Pi = \sum_{j=1}^{k} A_j - I$ and $\Gamma_i = \sum_{j=1}^{i} A_j - I$.

The rank (r) test $(r = 0, 1, \ldots, g-1)$ of Π matrix gives the number of cointegration relations between the variables. If the rank of Π matrix is $1 < \mathrm{rank}(\Pi) < g$, then $\Pi = \alpha_{g\times r} * \beta_{r\times g}{}' = \begin{pmatrix} \alpha_{11} \\ \alpha_{12} \end{pmatrix} (\, \beta_{11} \;\; \beta_{12} \,)$, β matrix gives the cointegrating parameters (β_1, β_2), and α matrix gives the adjustment parameters (α_1, α_2). Johansen's method proposes trace $\lambda_{\mathrm{Trace}}(r)$ and likelihood ratio tests for identifying

Table 2: Sample details.

Group	Commodity	Observations	Start date	End date	Q/B	Trading unit
Bullion	Gold	3996	6-Feb-06	31-Dec-19	10 gm	1 kg
	Silver	4166	26-May-05	31-Dec-19	1 kg	30 kg
Metal	Aluminum	3953	4-Jan-06	31-Dec-19	1 kg	5 tons
	Copper	1462	14-Feb-06	29-Nov-19	1 kg	1 mt
	Lead	3525	2-Jul-07	31-Dec-19	1 kg	5 tons
	Nickel	3673	8-Feb-07	31-Dec-19	1 kg	250 kg
	Zinc	3864	2-May-06	31-Dec-19	1 kg	5 tons
Energy	Crude oil	3990	2-Jan-06	18-Dec-19	1 barrel	100 barrel
	Natural gas	3827	20-Oct-06	31-Dec-19	mmbtu	1250 mmbtu

Note. (i) Q/B and T.U. refers to quotation per base value and trading unit. (ii) Trading unit for gold, silver, and nickel is expressed in kilogram, whereas for Aluminum, lead, and zinc, it is in tons. Trading unit of copper refers to million tons. Similarly, for crude oil and natural gas, these are barrel and mmbtu, respectively.

Table 3: Commodity wise total value of trade (%) in Multi Commodity Exchange Limited (MCX).

Group	Commodity	2006	2010	2015	2017	2019
Bullion	Gold	88.83	94.58	100.00	99.40	97.15
	Silver	87.28	97.48	98.75	99.79	100.00
Metal	Aluminum	75.83	100.00	91.97	85.22	89.37
	Copper	99.98	100.00	100.00	99.31	99.80
	Lead	0.00	100.00	99.21	98.06	96.73
	Zinc	99.62	100.00	99.72	97.00	97.65
Energy	Crude oil	100.00	100.00	98.46	99.72	90.16
	Natural gas	100.00	100.00	100.00	100.00	100.00

Source: compiled from Fortnightly Market Review, Forward Market Commission and SEBI, India (2005–2019).

and estimating the number of cointegrating vectors. The tests can be defined as follows:

$$\text{Trace Statistics: } \lambda_{\text{Trace}}(r) = -T\sum_{i=r+1}^{n}\ln\left(1-\widehat{\lambda}_i\right). \quad (6)$$

λ_{Trace} test statistics tests the null hypothesis of the number of cointegrating vector (r) s against the alternative hypothesis $(r+1)$.

$$\text{Maximum Eigenvalue statistics}: \lambda_{\text{Max}}(r, r+1) = -T\ \ln\left(1-\widehat{\lambda}_{r+1}\right). \quad (7)$$

λ_{Trace} test statistics tests the null hypothesis of the number of cointegrating vector (r) s against the alternative hypothesis (r).

A vector error correction model (VECM) exists for a set of cointegrated variables (Engle and Granger [67], which can be expressed in a bivariate case with lag 1 as follows:

$$\begin{pmatrix}\Delta F_t\\ \Delta S_t\end{pmatrix} = \begin{pmatrix}\delta_1\\ \delta_2\end{pmatrix} + \begin{pmatrix}\Gamma_{11}\Gamma_{12}\\ \Gamma_{21}\Gamma_{22}\end{pmatrix}\begin{pmatrix}\Delta F_{t-1}\\ \Delta S_{t-1}\end{pmatrix} + \begin{pmatrix}\alpha_f\\ \alpha_s\end{pmatrix}\left(F_{t-1}-\beta_2 S_{t-1}\right) + \begin{pmatrix}\varepsilon_{ft}\\ \varepsilon_{st}\end{pmatrix}. \quad (8)$$

For the futures market to error correction, $\alpha_f < 0$, and similarly, for spot market to error correction, $\alpha_s > 0$. α_f and α_s represent the coefficients of error correction term and it shows short-run adjustment factors. Error correction terms show how fast the disequlibrium error adjusts to the long-run equilibrium path.

After estimating the cointegrating vector and vector error correction model, the Granger causality test [68, 69] can be used to find out the short-run causality and long-run causality between spot and futures price. The vector error correction model (VECM) in (8) can be represented in the more general form for k^{th} order lag as follows:

$$\Delta FP_t = \delta_1 + \sum_{i=1}^{k} \Gamma_{fp,i} \Delta FP_{t-i} + \sum_{i=1}^{k} \Gamma_{sp,i} \Delta SP_{t-i} + \alpha_1 \left(FP_{t-i} - \beta SP_{t-i}\right) + \varepsilon_{fp}, \quad (9)$$

$$\Delta SP_t = \delta_1 + \sum_{i=1}^{k} \Gamma_{sp,i} \Delta SP_{t-i} + \sum_{i=1}^{k} \Gamma_{fp,i} \Delta FP_{t-i} + \alpha_2 \left(FP_{t-i} - \beta SP_{t-i}\right) + \varepsilon_{sp}. \quad (10)$$

The null hypothesis $\begin{pmatrix} \Gamma_{11}\Gamma_{12} \\ \Gamma_{21}\Gamma_{22} \end{pmatrix} \left(\Delta S_{t-1} \right) = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$ implies that lagged terms $\begin{pmatrix} \Delta F_{t-1} \\ \Delta S_{t-1} \end{pmatrix}$ can be tested for short-run causality and with standard likelihood ratio test with χ^2 distribution between spot and futures prices expressed as follows:

$$\begin{pmatrix} \Delta F_t \\ \Delta S_t \end{pmatrix} = \begin{pmatrix} \delta_1 \\ \delta_2 \end{pmatrix} + \begin{pmatrix} \Gamma_{11}\Gamma_{12} \\ \Gamma_{21}\Gamma_{22} \end{pmatrix} \begin{pmatrix} \Delta F_{t-1} \\ \Delta S_{t-1} \end{pmatrix} + \begin{pmatrix} \alpha_f \\ \alpha_s \end{pmatrix} \left(F_{t-1} - \beta_2 S_{t-1}\right) + \begin{pmatrix} \varepsilon_{ft} \\ \varepsilon_{st} \end{pmatrix}. \quad (11)$$

The null hypothesis (H_0) for (9) H_0: $\sum_i^k \Gamma_{sp,i} = 0$ implies that the lagged values of ΔSP do not Granger cause ΔFP or there is no short-run causality between futures price and spot price. Similarily, in (10), the null hypothesis H_0: $\sum_i^k \Gamma_{fp,i} = 0$ shows that the lagged values of ΔFP do not Granger cause ΔSP or there is no short-run casusality between spot price and futures price.

5. Results and Discussion

5.1. Descriptive Statistics. Tables 4 and 5 show the descriptive statistics of the selected commodities for spot and futures returns. The average percentage return in the spot market is higher than the futures market for all the commodities. However, the futures return is negative for zinc and natural gas, which implies a downward bias of futures prices in the futures market. The standard deviation is higher in the spot market for all the commodities than that in the futures markets. It also shows that the spot market is highly volatile than the futures market. The spot return's unconditional distributions are negatively skewed for copper, whereas such distributions of the futures return are negatively skewed for gold, silver, aluminum, and zinc. Spot return distribution is platykurtic for gold, silver, lead, and zinc. However, the spot return distribution is leptokurtic for copper, nickel, crude oil, and natural gas. Spot return for aluminum shows the mesokurtic type of distribution. Futures return distribution is leptokurtic for all the commodities except zinc. Minimum spot return varies from −6.44% (for zinc) to −66.65% (for copper), and maximum spot return varies from 13.19% (for gold) to 82.70% (for natural gas), as shown in Table 4. Similarly, minimum futures return varies from −6.33% (for copper) to −15.90% (for silver), and maximum futures return varies from 5.47% (for gold) to 22.17% (for lead), as shown in Table 5.

5.2. Stationarity Test. Augmented Dickey–Fuller (ADF) test results are presented in Table 6. The test shows that the log of spot and futures prices for level is nonstationary for all the commodities, alike prior studies [15, 16, 18–20, 22, 23, 26, 28, 50]. The null hypothesis of nonstationary is statistically not significant for both the price series in the level. However, the null hypothesis is statistically significant at 1% level of significance for both the spot and futures prices in difference. Thus, the test indicates that the difference of log spot and futures prices is integrated with order 1 for all the commodities. The result of the unit root test directs to proceed for the cointegration analysis, where the first condition, i.e., both the series, must be nonstationary in level and integrated of order one for the Johansen–Juselius (J-J) test needs to be satisfied.

5.3. Granger Causality Test. Before estimating the cointegration test in vector autoregressive (VAR) framework, the Granger causality test is conducted to know if any unidirectional or bidirectional causality relationship exists between spot and futures prices, in line with earlier research [15, 18–20, 22]. Granger causality test is estimated following the equations (10) and (11). The estimation results from the Granger causality test are presented in Table 7. The null hypothesis that spot return does not Granger cause futures return is rejected for gold, silver, aluminum, lead, nickel, zinc, and crude oil. It implies that the spot returns cause futures returns in these commodities. The null hypothesis cannot be rejected for copper and natural gas. It implies that spot return does not cause futures return for copper and natural gas. The null hypothesis that futures return does not Granger cause spot return is rejected for all the commodities. Therefore, futures return Granger causes spot returns for all the commodities. Granger causality test suggests a bidirectional causality relationship between spot and futures prices for gold, silver, aluminum, lead, nickel, zinc, and crude oil. However, futures return does not Granger cause the spot return for copper and natural gas. As the Granger test suggests bidirectional causality between spot and futures prices for most of the commodities, there is a need to explore their meaningful relationship in the long run and short run using the J-J cointegration test followed by the estimation of a dynamic VECM.

Table 4: Descriptive statistics of selected commodities for spot return.

Group	Commodity	Mean	Std. Dev	Skewness	Kurtosis	Min	Max	J-B stat
Bullion	Gold	0.0183	0.0199	0.2761	−2.3658	−0.0680	0.1319	44.4369
	Silver	0.0338	0.0284	0.2558	−2.5279	−0.0835	0.1612	34.8346
Base metals	Aluminum	0.0290	0.0247	0.3915	0.3661	−0.0822	0.1703	758.5985
	Copper	0.0134	0.0526	−3.2404	41.2291	−0.6665	0.2538	1995.4000
	Lead	0.0198	0.0332	0.1312	−1.7161	−0.1095	0.1692	77.1338
	Nickel	0.0231	0.0392	0.5778	1.1388	−0.1159	0.3037	918.3396
	Zinc	0.0288	0.0307	0.4878	−1.6323	−0.0644	0.1575	168.4567
Energy	Crude oil	0.0337	0.0491	1.9676	5.8151	−0.0952	0.4251	5898.1310
	Natural gas	0.0790	0.1116	2.8257	7.6306	−0.0912	0.8271	7752.7000

Table 5: Descriptive statistics of selected commodities for futures return.

Group	Commodity	Mean	Std. Dev	Skewness	Kurtosis	Min	Max	J-B stat
Bullion	Gold	0.0007	0.0104	−0.4798	3.3165	−0.0800	0.0547	2550.9430
	Silver	0.0010	0.0153	−0.8739	8.4257	−0.1591	0.0880	9547.0380
Base metals	Aluminum	0.0002	0.0146	−0.7620	6.9756	−0.1561	0.0587	6458.7260
	Copper	0.0005	0.0145	0.5425	2.0853	−0.0633	0.1060	1652.9410
	Lead	0.0003	0.0227	0.8976	6.7044	−0.1144	0.2218	4343.0010
	Nickel	0.0000	0.0226	0.2799	0.1735	−0.1013	0.1315	516.9168
	Zinc	−0.0001	0.0195	−0.0179	−1.0128	−0.0861	0.0832	235.8748
Energy	Crude oil	0.0004	0.0167	0.0552	0.4974	−0.0872	0.1078	776.1763
	Natural gas	−0.0002	0.0234	1.0416	4.5081	−0.0892	0.1917	3249.1260

Table 6: Unit root test of spot and futures prices (level and difference) for the selected commodities.

Group		Levels (log)			First difference (log)			
	Commodity	Constraint	Spot	Future	Constraint	Spot	Future	Integration
Bullion	Gold	I and T	−3.01	−2.90	I	−10.48	−10.42	I (1)
	Silver	I and T	−1.72	−2.12	I	−10.67	−10.22	I (1)
Base metals	Aluminum	I and T	−1.85	−1.81	I	−10.37	−10.77	I (1)
	Copper	I and T	−1.90	−2.15	None	−11.54	−8.49	I (1)
	Lead	I	−1.67	−1.79	None	−9.74	−9.71	I (1)
	Nickel	I	−1.89	−1.73	I and T	−11.26	−10.84	I (1)
	Zinc	I	−1.22	−1.16	None	−10.69	−10.50	I (1)
Energy	Crude oil	I and T	−1.76	−1.80	None	−12.37	−10.92	I (1)
	Natural gas	I	−2.20	−2.05	None	−10.12	−10.27	I (1)

Note. The Fuller critical values for ADF test at 1%, 5%, and 10% are -3.43, −2.86, −2.57, respectively for constant. The Fuller critical values for ADF test at 1%, 5%, and 10% are -3.96, −3.41, and −3.12, respectively for constant + time trend (denoted by I and T). The Fuller critical values for ADF test at 1%, 5%, and 10% are −2.58, −1.95, and −1.62, respectively for no constant or time trend (denoted by none).

Table 7: Granger causality test of spot and futures returns for the selected commodities.

Group	Commodity	Spot does not Granger cause futures		Futures does not Granger cause spot	
		F-stat	*P*-value	F-stat	*P*-value
Bullion	Gold	6.052	0.001	175.114	0.001
	Silver	2.193	0.031	140.548	0.001
Base metals	Aluminum	9.254	0.001	23.913	0.001
	Copper	0.391	0.892	62.022	0.001
	Lead	5.235	0.001	37.201	0.001
	Nickel	3.135	0.001	46.284	0.001
	Zinc	3.164	0.001	69.612	0.001
Energy	Crude oil	3.542	0.001	116.842	0.001
	Natural gas	0.781	0.592	76.021	0.001

Note. Spot and futures represent spot return and futures return, respectively. p value (0.001) refers to the significance at 1% level.

5.4. Johansen and Juselius (J-J) Cointegration Analysis. Following the stationarity test results of the previous section, the J-J cointegration test is estimated for the spot and futures prices, which are integrated of order one. Identification of the cointegrating relationship among the variables is important, as the VAR model in the first difference is misspecified for the two nonstationary variables, which are cointegrated. After identifying the cointegration relationship(4), VAR will include residuals from the vectors (lagged one period) in the VECM (Engle and Granger, 1987). The J-J cointegration test is estimated by following the Johansen and Juselius (1990) method. The results are presented in Table 8.

λ_{trace} test rejects the null hypothesis of no cointegrating vectors $(r = 0)$ at 1% significance level for silver, aluminum, copper, lead, nickel, and zinc, and it also rejects the same at 5% level for crude oil. Hence, it accepts the null hypothesis of more than zero cointegrating vectors. λ_{trace} test accepts the null of no cointegrating vector in the case of gold and natural gas. It also accepts the $(r \leq 1)$ cointegrating vector's null hypothesis against the alternative hypothesis of more than one cointegrating vectors $(r > 1)$ for silver, aluminum, copper, lead, nickel, and zinc. Similarly, $\lambda_{\max}$ test rejects the null hypothesis of no cointegrating vectors $(r = 0)$ at 1% level of significance for silver, aluminum, copper, lead, nickel, zinc, and crude oil. So, it accepts the alternative hypothesis of one cointegrating vector $(r = 1)$. $\lambda_{\max}$ test accepts the null hypothesis of one cointegrating vector $(r = 1)$ against the null hypothesis of two cointegrating vector $(r = 2)$. Both λ_{trace} and $\lambda_{\max}$ tests suggest the presence of one cointegrating vector for silver, aluminum, copper, lead, nickel, zinc, and crude oil. The tests reject the presence of any cointegrating vector for gold and natural gas. Hence, a dynamic VECM is estimated for all those commodities, where there is a presence of a cointegrating relationship between the spot and futures prices.

5.5. Vector Error Correction Model. Results from the estimation of VECM (8) and (9) for spot and futures prices are presented in Tables 9 and 10. Accordingly, the results are interpreted for different commodities separately.

5.5.1. Silver. The coefficient of the error correction term α_s is negative and not significant. It implies that the spot price is not responding to the previous period's equilibrium. α_F is positive, which implies that silver's futures price is responding positively to the previous period's equilibrium. In ECM for spot price, the coefficients are negative and significant up to lag 5. However, the coefficients for the futures price are positive and significant up to lag 5. It shows that lagged spot price has a negative impact, and lagged futures price positively impacts the spot price. In ECM for the futures price, the spot price coefficients positively impact futures prices up to lag 5, whereas lagged futures price has a negative impact on the current futures price. Spot price at lag 1 has the highest impact on the current futures price than the higher lags. ECM result implies that the previous day spot prices have a positive impact on the futures price. Thus, it is established that the futures market leads the spot market and not vice versa in the price discovery process.

5.5.2. Aluminium. The error correction term's coefficient is negative and statistically not significant at 5% level of significance. In ECM for spot price, lagged spot price coefficients up to lag 5 are negative and statistically significant. It is found that the coefficients for both spot and futures prices are declining throughout the lag. It means that the previous spot price at lag 1 has a more negative impact on the current spot price than other previous prices at higher lags. Futures price coefficients are positively influencing the current spot price. In ECM for the futures price, α_F is positive and statistically significant at 1% level. It shows that the futures price's short-run deviations would be adjusted in an upward direction towards the long-run equilibrium. The coefficients for lagged spot prices positively impact the current futures price, and the coefficients of lagged futures prices have a negative impact on the current futures price. The results suggest that the futures market leads to the spot market, and the spot market does not lead to the futures market in price discovery.

5.5.3. Copper. The coefficient of the error correction term α_s is negative and statistically significant at 5% level. When α_s is negative and statistically significant, spot price corrects the deviations from the long-run equilibrium. So, if the actual equilibrium value is high, the negative error correction term will reduce it, and if the equilibrium value is too low, the error correction term will raise it. The spot price is responsive to the previous period's equilibrium error. In ECM for the spot price, the lagged spot price coefficients up to lag 5 are negative and statistically significant at 1% level, whereas lagged futures price coefficients are positive. ECM for the futures price (11) is not statistically significant. Therefore, the impact of the futures price in adjusting the error towards long-run equilibrium can be ruled out.

5.5.4. Lead. The coefficient of the error correction term α_s is negative and statistically not significant. In ECM for spot price, the spot price coefficients up to lag 6 are negative and statistically significant at 1% level. Previous spot price up to lag 8 has an impact on the current spot price, and the declining effect of the lagged spot price varies from −0.44 in lag 1 to -0.21 in lag 8. Futures price coefficients up to lag 8 affect the current spot price positively. In ECM for the futures price, α_F is positive and statistically significant at 5% level. It shows that the futures price's short-run deviations would be adjusted in an upward direction towards the long-run equilibrium. Coefficients for lagged spot prices up to lag 8 have a positive impact on the current futures price. Similarly, the coefficients for lagged futures prices up to lag 8 negatively affect the current futures price. The results also show

Table 8: Johansen and Juselius cointegration rank test of spot and futures prices.

Group	Commodity	Lag length	Maximum trace value		Maximum eigen value		Remark
			H_0: rank = 0 vs H_1: rank = 1	H_0: rank = 1 vs H_1: rank = 2	H_0: rank = 0 vs H_1: rank = 1	H_0: rank = 1 vs H_1: rank = 2	
Bullion	Gold	10	18.84	2.44	14.40	2.44	NS
	Silver	6	37.22	3.65	33.57	3.65	1
Base metals	Aluminum	6	60.95	2.87	58.08	2.87	1
	Copper	7	72.45	3.66	68.80	3.66	1
	Lead	9	55.10	3.37	51.73	3.37	1
	Nickel	10	29.77	4.31	25.46	4.31	1
	Zinc	8	51.04	2.85	48.19	2.85	1
Energy	Crude oil	10	23.50	3.65	20.85	3.65	1
	Natural gas	4	14.90	3.08	11.81	3.08	NS

Note. Critical values of λ_{trace} $(r = 0)$ for 1%, 5%, and 10% significance levels are 24.6, 19.96, and 17.85, respectively. Critical values of λ_{trace} $(r = 1)$ for 1%, 5%, and 10% are 12.97, 9.24, and 7.25, respectively. Critical values of λ_{Max} $(r = 0)$ for 1%, 5%, and 10% are 20.2, 15.67, and 13.75, respectively. Critical values of λ_{Max} $(r = 1)$ for 1%, 5%, and 10% are 12.97, 9.27, and 7.52, respectively. AIC lag selection criteria are used for the estimation.

Table 9: Vector error correction model for spot price of the selected commodities.

Coefficients	Silver	Aluminum	Copper	Lead	Nickel	Zinc	Crude oil
α_s	−0.01	−0.06*	−0.19**	−0.15*	−0.07*	−0.13***	−0.02***
	(−0.98)	(−2.44)	(−8.34)	(−2.54)	(−2.17)	(−3.45)	(−1.39)
ΔS_{t-1}	−0.43***	−0.25***	−0.25***	−0.44***	−0.48***	−0.57***	−0.43***
	(−14.81)	(−8.08)	(−9.33)	(−10.34)	(−11.45)	(−15.68)	(−14.51)
ΔS_{t-2}	−0.32***	−0.19***	−0.52***	−0.42***	−0.38***	−0.52***	−0.27***
	(−10.20)	(−5.65)	(−19.63)	(−8.38)	(−7.76)	(−11.10)	(−8.31)
ΔS_{t-3}	−0.23***	−0.17***	−0.24***	−0.35***	−0.28***	−0.40***	−0.17***
	(−7.09)	(−4.87)	(−8.05)	(−6.18)	(−5.19)	(−8.33)	(−4.97)
ΔS_{t-4}	−0.16***	−0.13***	−0.30***	−0.37***	−0.33***	−0.35***	−0.05
	(−5.09)	(−3.61)	(−10.93)	(−6.15)	(−6.02)	(−6.90)	(−1.39)
ΔS_{t-5}	−0.06*	−0.11**	−0.23***	−0.32***	−0.25***	−0.26***	−0.04
	(−2.26)	(−2.96)	(−8.71)	(−5.04)	(−4.35)	(−5.01)	(−1.16)
ΔS_{t-6}	—	—	−0.23***	−0.23***	−0.20***	−0.21***	−0.04
	—	—	(−8.97)	(−3.47)	(−3.43)	(−4.12)	(−1.06)
ΔS_{t-7}	—	—	—	−0.18	−0.15	−0.21	−0.17
	—	—	—	(−2.79)	(−2.58)	(−4.46)	(−5.05)
ΔS_{t-8}	—	—	—	−0.21**	−0.29***	—	−0.12***
	—	—	—	(−3.25)	(−5.31)	—	(−3.49)
ΔS_{t-9}	—	—	—	—	−0.15**	—	−0.14***
	—	—	—	—	(−3.08)	—	(−4.98)
ΔF_{t-1}	0.68***	0.39***	0.11***	0.73***	0.75***	0.78***	0.88***
	(28.59)	(11.65)	(17.84)	(14.64)	(16.80)	(20.19)	(26.89)
ΔF_{t-2}	0.31***	0.22***	0.23***	0.51***	0.52***	0.66***	0.35***
	(9.59)	(5.86)	(3.43)	(8.54)	(9.51)	(13.57)	(8.41)
ΔF_{t-3}	0.28***	0.11**	0.57***	0.39***	0.32***	0.49***	0.22***
	(8.62)	(2.95)	(8.28)	(5.99)	(5.35)	(8.97)	(5.06)
ΔF_{t-4}	0.21***	0.17***	0.17*	0.37***	0.30***	0.39***	0.14***
	(6.35)	(4.44)	(2.49)	(5.28)	(4.73)	(6.75)	(3.31)
ΔF_{t-5}	0.12***	0.09***	0.35*	0.33***	0.31***	0.28***	0.03
	(3.84)	(2.21)	(5.12)	(4.47)	(4.74)	(4.69)	(0.71)
ΔF_{t-6}	—	—	0.16*	0.21**	0.24***	0.22***	0.07
	—	—	(2.31)	(2.74)	(3.66)	(3.68)	(1.64)
ΔF_{t-7}	—	—	—	0.15*	0.16*	0.21***	0.10
	—	—	—	(1.97)	(2.28)	(3.17)	(2.36)
ΔF_{t-8}	—	—	—	0.28***	0.23***	—	0.13***
	—	—	—	(3.72)	(3.74)	—	(3.01)
ΔF_{t-9}	—	—	—	—	0.23***	—	0.12**
	—	—	—	—	(3.89)	—	(2.89)
$\overline{R}^2$	0.33	0.09	0.33	0.19	0.22	0.23	0.35
F − Stat	77.43	14.17	55.63	14.55	17.26	29.96	41.20
LM (χ^2)	32.07	25.29	29.06	54.07	51.16	11.91	51.25
	(0.13)	(0.39)	(0.41)	(0.54)	(0.11)	(0.16)	(0.11)

Note. Figures in parenthesis refer to respective t-stat for the coefficients.***,**, and* represent statistical significance at 1%, 5%, and 10%, respectively. Statistical significance of coefficients is considered at 5% level of significance. F-statistics is significant at 1% level for all the commodities.LM (χ^2) value shows the chi-square value of Breusch–Godfrey LM test for serial autocorrelation.

Table 10: Vector error correction model for futures price of the selected commodities.

Coefficients	Silver	Aluminum	Copper	Lead	Nickel	Zinc	Crude oil
α_F	0.08 ***	0.10 ***	0.01	0.17 **	0.05	0.07 *	0.04 **
	(4.30)	(4.50)	(0.23)	(3.19)	(1.63)	(2.04)	(3.01)
ΔS_{t-1}	0.14 ***	0.20 ***	−0.02	0.22 ***	0.15 ***	0.12 ***	0.08 **
	(4.05)	(7.34)	(−0.03)	(6.03)	(3.90)	(3.54)	(3.16)
ΔS_{t-2}	0.08 *	0.16 ***	0.01	0.18 ***	0.15 **	0.10 *	0.08 **
	(2.15)	(5.32)	(1.11)	(4.29)	(3.21)	(2.48)	(2.58)
ΔS_{t-3}	0.08 *	0.13 ***	0.07	0.18 ***	0.17 ***	0.13 **	0.08 **
	(1.97)	(4.18)	(0.23)	(3.73)	(3.42)	(2.78)	(2.75)
ΔS_{t-4}	0.06	0.13 ***	0.04 *	0.15 **	0.08	0.16 ***	0.11 ***
	(1.54)	(4.10)	(1.02)	(3.02)	(1.62)	(3.45)	(3.66)
ΔS_{t-5}	0.10 **	0.14 ***	0.03	0.17 **	0.12 *	0.17 ***	0.12 ***
	(3.16)	(4.17)	(0.62)	(3.22)	(2.16)	(3.54)	(3.85)
ΔS_{t-6}	—	—	0.04	0.18 **	0.08	0.12 **	0.11 ***
	—	—	(0.05)	(3.17)	(1.56)	(2.61)	(3.40)
ΔS_{t-7}	—	—	—	0.15 **	0.07	0.02	−0.01
	—	—	—	(2.66)	(1.27)	(0.52)	(−0.258)
ΔS_{t-8}	—	—	—	0.21 ***	−0.09 *	—	0.05 *
	—	—	—	(3.71)	(−1.86)	—	(1.69)
ΔS_{t-9}	—	—	—	—	0.01	—	0.04
	—	—	—	—	(0.04)	—	(1.63)
ΔF_{t-1}	−0.07 *	−0.14 ***	−0.02	−0.08 *	−0.04	−0.05	0.02
	(−2.51)	(−4.61)	(−0.76)	(−1.98)	(−0.86)	(−1.45)	(0.65)
ΔF_{t-2}	−0.10 **	−0.15 ***	0.03	−0.15 **	−0.12 *	−0.08 *	−0.13 ***
	(−2.77)	(−4.43)	(1.09)	(−2.91)	(−2.36)	(−1.85)	(−3.55)
ΔF_{t-3}	−0.03	−0.12 ***	0.02	−0.21 ***	−0.23 ***	−0.15 **	−0.09 *
	(−0.89)	(−3.57)	(0.81)	(−3.73)	(−4.11)	(−2.86)	(−2.33)
ΔF_{t-4}	−0.09 *	−0.11 **	0.03	−0.17 **	−0.16 **	−0.15 **	−0.09 *
	(−2.25)	(−3.01)	(0.95)	(−2.88)	(−2.76)	(−2.89)	(−2.18)
ΔF_{t-5}	−0.07 *	−0.14 ***	0.07	−0.22 ***	−0.06	0.20 ***	−0.13 **
	(−1.89)	(−3.89)	(2.32)	(−3.50)	(−0.96)	(−3.53)	(−3.26)
ΔF_{t-6}	—	—	0.03	−0.22 ***	−0.09	−0.19 ***	−0.12 **
	—	—	(1.18)	(−3.39)	(−1.49)	(−3.49)	(−2.95)
ΔF_{t-7}	—	—	—	−0.20 **	−0.09	−0.09 *	−0.09 *
	—	—	—	(−3.04)	(−1.47)	(−1.85)	(−2.34)
ΔF_{t-8}	—	—	—	−0.19 **	0.01	—	−0.06
	—	—	—	(−2.49)	(0.03)	—	(−1.55)
ΔF_{t-9}	—	—	—	—	0.09	—	−0.04
	—	—	—	—	(1.59)	—	(−1.08)
$\overline{R}^2$	0.02	0.04	0.01	0.06	0.04	0.03	0.04
F − Stat	3.44	7.20	1.35	3.98	3.45	2.47	2.96
LM (χ^2)	32.07	25.29	29.06	54.07	51.16	11.91	51.25
	(0.13)	(0.39)	(0.41)	(0.54)	(0.11)	(0.16)	(0.11)

that the futures market leads spot market in price discovery and not vice versa.

5.5.5. Nickel. The coefficient of the error correction term α_s s negative and statistically not significant. In ECM for spot price, the spot price coefficients up to lag 9 are negative and statistically significant at 1% level. Previous spot prices up to lag 9 impact the current spot price, and the declining effect of the lagged spot price varies from -0.48 in lag 1 to −0.15 in lag 9. Futures price coefficients up to lag 9 affect positively the current spot price. In ECM for the futures price, α_F is positive and statistically not significant. So, it suggests that short-run deviations of the futures price are not adjusting towards the long-run equilibrium. The coefficients for lagged spot prices up to lag 3 have a positive impact on the current futures price. Similarly, the lagged futures price's coefficients up to lag 6 have a negative impact on the current futures price. Thus, the results show that both the spot and futures markets are not adjusting in short-run deviations towards long-run equilibrium.

5.5.6. Zinc. The coefficient of the error correction term α_s is negative and statistically significant. When α_s is negative and statistically significant, spot price corrects the deviations from the long-run equilibrium. The spot price is responsive to the previous period's equilibrium error. In ECM for the spot price, coefficients up to lag 5 are negative and statistically significant. The result shows that coefficients for both spot and futures prices are declining for lag. It means that the spot price at lag 1 has a more negative impact on the current spot price than the spot price of higher lags. Futures price coefficients up to lag 6 are positively influencing the current spot price. In ECM for the futures price, α_F is positive and statistically not significant. It implies that short-run deviations of the futures price are not adjusting towards the long-run equilibrium. The coefficients for lagged spot prices up to lag 6 positively impact the current futures price. Lagged futures price coefficients at lag 1 and lag 2 are statistically not significant. However, lagged futures price coefficients from lag 3 to lag 6 have a negative impact on the current futures price. Thus, it can be established that the spot market leads to the futures market and not vice versa.

5.5.7. Crude Oil. The coefficient of the error correction term α_s is negative and statistically significant. When α_s is negative and statistically significant, the spot price corrects the deviations from the long-run equilibrium and responsive to the previous period's equilibrium error. In ECM for the spot price, coefficients for lagged spot price up to lag 3 have a negative impact on the current spot price. Lagged futures prices up to lag 4, and at lag 8 and lag 9 are having a positive impact on the current spot price. Futures price coefficients are positively influencing the current spot price. In ECM for the futures price, α_F is positive and statistically significant at 5% level. It shows that the futures price's short-run deviations would be adjusted in an upward direction towards the long-run equilibrium. The coefficients for lagged spot price up to lag 5 have a positive impact on the current futures price, and the coefficients for lagged futures price at lag 1, lag 5, and lag 6 have a negative effect on the current futures price. Thus, both spot and futures markets contribute to the process of price discovery, as they can adjust to the short-run deviations towards the long-run equilibrium.

VECM regressions for spot and futures prices are significant for silver, aluminum, lead, nickel, zinc, and crude oil. However, the error correction model for the futures price of copper is not statistically significant. $\overline{R}^2$ the error correction model for the spot price (10) is higher than the futures price (11). The results from the model's estimation imply that the error correction term α_s and the lagged futures and spot prices explain the model better than the futures price equation. Breusch–Godfrey LM χ^2 test for serial autocorrelation is conducted to test the null hypothesis of no autocorrelation at the respective lag for all the commodities. Values are not statistically significant for all the commodities, which imply no autocorrelation problem in the dataset for all the commodities. It also confirms that the selected lags for the commodities are appropriate for estimating a vector autoregressive model.

6. Concluding Remarks and Policy Implications

The above empirical findings imply no lead-lag relationship between the spot and futures prices for gold, silver, aluminum, lead, nickel, zinc, crude oil, and natural gas. Market participants can use price as a source of information from both the spot and the futures markets. However, the spot markets do not impact the futures markets for copper and natural gas. The J-J cointegration test reveals that the spot and futures prices move together in a long-run equilibrium path for silver, aluminum, copper, lead, nickel, zinc, and crude oil. The test rejects any evidence of the cointegrating relationship of spot and futures prices for gold and natural gas. This implies the possibility of random walk nature in the spot and futures prices, and arbitrage fails to correct the disequilibrium.

The existence of a cointegrating relationship implies that both the spot and futures markets may have short-run disequilibrium. However, this can be corrected by the arbitrage process. Spot markets play a crucial role in adjusting any short-run disequilibrium error for copper and zinc. However, futures market is more dominant in the case of silver, aluminum, and lead in adjusting the short-run disequilibrium. Both spot and futures markets are responsible for correcting the short-run disequilibrium for nickel and crude oil. As the Indian commodity futures market is growing rapidly, the findings have implications for the various market participants to implement trading and arbitrage strategy. It will also help the policy makers to check the stability of the market.

Policymakers and regulators should highlight the efficiency of futures markets and enhance market participation by effectively applying trading strategies that allow market participants to take advantage of data accessibility [15]. In this regard, the outcomes can assist traders in more accurately estimating price changes, permitting them to confirm when investing and arbitraging opportunities emerge and how long they will persevere in the market [25]. As well, the Indian government should develop its institutional infrastructure to allow for more seamless commodity transactions consistent with market advances [23]. As such, expanded policies and enforcement are required, as well as expanded broker and dealer involvement in the commodities market, the insertion of exotic commodity derivatives, and heightened transparency and disclosure [17]. Besides, through investor awareness campaigns, the SEBI can strive to strengthen public awareness about the latest financial instruments [21].

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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