Journal of
Risk and Financial Management

Article

Price Discovery Mechanism and Volatility Spillover between National Agriculture Market and National Commodity and Derivatives Exchange: The Study of the Indian Agricultural Commodity Market

Mohit Garg [1], Shelly Singhal [1], Kiran Sood [1], Ramona Rupeika-Apoga [2,*] and Simon Grima [2,3]

1 Chitkara Business School, Chitkara University, Rajpura 140401, Punjab, India
2 Faculty of Business, Management and Economics, University of Latvia, LV-1586 Riga, Latvia
3 Department of Insurance, Faculty of Economics Management and Accountancy, University of Malta, MSD 2080 Msida, Malta
* Correspondence: ramona.rupeika-apoga@lu.lv

Abstract: Agricultural commodity markets are critical to the global economy. This study investigates the price discovery mechanism, lead-lag relationship, and volatility spillover between spot prices on the National Agriculture Market (E-NAM) and futures and spot prices on the National Commodity and Derivative Exchange (NCDEX) in the Indian agricultural commodity market. The Johansen Cointegration, Vector Error Correction (VEC), Granger causality tests, and bivariate GARCH models were applied to daily data from April 2016 to December 2020 for twelve agricultural commodities traded on the E-NAM and NCDEX. We discovered the long-run relationship using the Johansen Cointegration test and concluded that the NCDEX spot and futures market is dominant in the price discovery mechanism, and the NCDEX futures and spot markets lead the E-NAM spot prices having a unidirectional or bidirectional relationship. Furthermore, the bivariate GARCH model suggested a volatility spillover from E-NAM spot prices to NCDEX futures and spot markets for most commodities, except for bajra, barley, and jeera, which have no volatility spillover. The study's findings have important implications for various stakeholders, including policymakers, farmers, investors, traders, and others who want to reduce price risks by using information from the E-NAM market's spot prices.

Keywords: E-NAM; commodity markets; agricultural markets; Agricultural Produce Market Committee (APMC) act; volatility spillover

Citation: Garg, Mohit, Shelly Singhal, Kiran Sood, Ramona Rupeika-Apoga, and Simon Grima. 2023. Price Discovery Mechanism and Volatility Spillover between National Agriculture Market and National Commodity and Derivatives Exchange: The Study of the Indian Agricultural Commodity Market. *Journal of Risk and Financial Management* 16: 62. https://doi.org/10.3390/jrfm16020062

Academic Editor: Zuopeng (Justin) Zhang

Received: 29 November 2022
Revised: 13 January 2023
Accepted: 16 January 2023
Published: 19 January 2023

1. Introduction

A commodity market is where several agricultural and non-agricultural commodities and their derivative products are exchanged. Commodities are undifferentiated to the average investor, but as inflation rates rise, investors may consider commodities as investments that can help diversify a portfolio. Commodities are tangible goods consumed directly or used to produce other goods. Precious metals, natural gas, oil, cotton, and other commodities are examples of common commodities. The changing economic environment emphasizes the need for more rigorous research and a better understanding of price discovery mechanisms in agricultural commodity markets.

On reviewing the literature, we have identified that different researchers in various agricultural commodities contexts have explored the price discovery mechanism and volatility spillover (Basavaraj and Chowdri 2013; Ding et al. 2021; Kim and Lim 2019). However, no consensus has been found in the results. Also, the price discovery mechanism and volatility spillover had not been identified by considering the National Agriculture Market (E-NAM) price series as a new spot price series in reference to future price series and the spot price series of the National Commodity and Derivative Exchange (NCDEX).

This study investigates the price discovery mechanism, lead-lag relationship, and volatility spillover between spot prices on E-NAM and futures and spot prices on NCDEX in the Indian agricultural commodity market. The Johansen cointegration, vector error correction (VEC), Granger causality tests, and bivariate GARCH models were applied to daily data from April 2016 to December 2020 for twelve agricultural commodities traded on the E-NAM portal and NCDEX. We discovered the long-run relationship using the Johansen cointegration method and concluded that the NCDEX spot market is dominant in the price discovery mechanism, and the NCDEX futures and spot markets lead the E-NAM spot prices.

The theoretical contribution of this study is an understanding of whether the three price series, namely E-NAM spot prices, NCDEX futures prices, and NCDEX spot prices, are cointegrated or not, the rate at which the long-run variables are adjusted to achieve long-run equilibrium, and how variations in one market affect the other market. Commodity markets for agricultural products are critical to the global economy. Understanding the price discovery mechanism of these markets is important for designing policy frameworks that support the economic goals of sustainable growth, inflation stability, poverty reduction, food security, and climate change mitigation.

This improves an economy's ability to compete in the market, making it a crucial pillar of any significant economy's financial system. Due to low labor costs, favorable demographics, and abundant natural resources during a global commodities boom, India has long been one of the world's fastest-growing emerging market economies (IMF 2023). India's economy was the fifth largest in the world in 2022, and it is expected to become the third largest by 2029 (IMF 2023). Commodity derivatives are essential for managing price risks in all major businesses and corporations. In contrast to other major global commodity exchanges, which allow access to a diverse range of institutional participants, the Indian commodity market was restricted to individuals and corporations until 2019. Only in 2019 did the Securities and Exchanges Board of India (SEBI) allow securities custodians to extend their custodial services to commodity market institutional players (WFE 2023). Given that India is a major producer or consumer of a variety of commodities, SEBI's initiatives have the potential to propel the Indian commodity derivatives market into the ranks of the world's most influential markets.

The study's findings have practical implications for farmers, investors, traders, and others who want to reduce price risks or speculate using information from the E-NAM market's spot prices. The study helps to reduce the arbitrage opportunities in the market by providing timely information through the newly introduced Indian spot market, i.e., E-NAM.

This paper is organized as follows. The introduction provides a brief context for the study and emphasizes why the topic is important, as well as the current state of the research field and gaps in the literature review. Section 2 delves into the development of the Indian agricultural commodity market. Section 3 discusses the data and methodology. Section 4 presents the results of the price discovery mechanism, lead-lag relationship, and volatility spillover among selected agricultural commodities in the E-NAM market spot price and the NCDEX futures and spot prices. Section 5 discusses the findings and concludes.

2. Background

A distinguishing feature of commodity markets is the importance of futures markets. In contrast to cash markets, which deal with the immediate transfer of goods, a futures market is based on purchasing or selling commodity contracts at a fixed price for potential physical delivery at a later date. A futures exchange allows buyers and sellers to trade commodity futures contracts openly and publicly report any market transactions. As a result of this activity, futures markets serve as a primary mechanism for price discovery and a central exchange for domestic and international market information, particularly for storable agricultural commodities with seasonal production patterns (USDA 2022; Bezzina and Grima 2012).

An agricultural commodity market is identical to an equity market, but rather than trading in shares, one trades in different types of commodities like wheat, rice, livestock, soybeans, etc. Just like the success of any investment depends on the return from that investment, in the same way, success in any sector also depends on the return from that sector (Bhatnagar et al. 2022). However, due to various factors, the returns on investment will likely fluctuate. The lack of standardization, a well-defined market, marketing facilities, knowledge about market information, involvement of intermediaries in the market, the overview regarding futures prices of products, etc., were some of the factors which push the agricultural market towards price risk (Rout et al. 2021b). Therefore, various researchers recommend the commodity futures market as a substitution scheme to overcome the price risk and stability of prices (Rajib 2015).

Futures prices provide the necessary indications of the future-ready (spot) price and demand and supply conditions for the various producers and consumers (Rout et al. 2021a). The futures price is the price at which the contract is undersigned for purchasing or selling goods or services that are to be sold or purchased at a future date. Spot prices are the prices of goods and services in the spot market. In addition, the future spot prices are the prices of the commodities that are expected to prevail in the spot market at the maturity of the futures contracts (Da Fonseca and Xu 2019).

However, with the introduction of India's new spot market, the National Agriculture Market (E-NAM), holding commodities is no longer a problem. Farmers can also use E-NAM receipts to store their goods in various warehouse storages to benefit from future price increases. Farmers can also obtain a loan by storing their goods in a warehouse and repaying the loan when the goods are sold. As goods are available on the market for a longer period of time, price levels may change. As a result of the newly introduced Indian spot market, E-NAM, farmers became aware of the cropping pattern and took advantage of higher prices in the future to overcome their price risk.

Commodity futures markets have had a long history of assisting commodity producers to hedge their commodity price risks. Financialization of commodity markets thus affects risk sharing in commodity markets through the dual roles of financial investors: as providers of liquidity to hedgers when trading to accommodate hedging needs and as consumers of liquidity from hedgers when trading for their own needs (Cheng and Xiong 2014; Abraham 2022; Chari and Christiano 2017; Ding et al. 2021). In India, the history of commodity futures trading dates back to the nineteenth century, when the Cotton Trade Association started futures trading in 1875. Later, cotton futures trading started in oilseed in Bombay (1900), raw jute and jute goods in Calcutta (1912), and wheat in Hapur (1913) (SAMCO 2022). Then the futures market developed for several commodities in India. In 2003, electronic trading of commodity derivatives with nationwide connected exchanges was introduced. The main idea behind the introduction of a centralized commodity futures exchange was to solve the issues of fragmented spot markets by enabling transparent price discovery (SAMCO 2022).

Price discovery is the function of the futures market that produces the best estimate of the future spot price of a commodity (Rout et al. 2021b). Price discovery also means a fair and transparent sale and purchase of commodities for not having any arbitrage opportunities. The trade in the futures market increases, but the contribution of farmers to the agricultural futures commodity market is negligible. This is mainly because of the deficiency of integration in India's futures and spot market (Basu 2020) and the lack of information delivery to the farmers (Grima 2012).

Much research has been conducted internationally and in India to discover the cointegration analysis and speed of adjustment in the futures market or the cash market through different approaches. Some of the researchers in India have examined the price discovery and lead-lag relationship between the futures and spot markets of agricultural commodity derivatives. Sehgal et al. (2012) concluded that the futures market had played the lead role in price discovery in most sample commodities except for turmeric. Basavaraj and Chowdri (2013) concluded that the futures market for red chili in India was outperforming the spot market in terms of forecasting future spot prices. Sharma (2015) concluded that futures were leading the spot market in the case of soya bean and soya oil, whereas two-way feedback was found in chickpeas and pepper. Similarly, other researchers (Kim and Lim 2019; Narayan and Sharma 2018; Sharma 2015) highlight the same concept that the futures market is more efficient than the spot market by using cointegration and causality tests on different farming products such as maize, black pepper, castor seed, chickpeas, soybean, black lentil, and sugar.

In addition, Srinivasan (2011) assessed the direction of volatility spillovers in the Indian spot-future commodity market using the bivariate EGARCH and reported that there is volatility spillover from the spot to the futures commodity market. Rout et al. (2021b) reported a similar direction for volatility spillover from spot to futures for most commodities studied. Naik and Jain (2002) studied the long-memory volatility model and suggested evidence of fractional integration in most of the agricultural commodity futures markets.

To integrate the spot and futures markets and make the agricultural information delivery system effective, the government of India launched E-NAM (the Electronic National Agriculture Market) in April 2016. It is a pan-India online dealing doorway to interlink the current Agricultural Produce Market Committee (APMC) markets for structuring a nationwide market for several agricultural commodities (E-NAM 2022).

With the two objectives of the price discovery mechanism and real-time price dissemination, the E-NAM aims to introduce a technology-enabled trading environment in regulated markets at the regional and national levels. In reality, the common agricultural market E-NAM can benefit different stakeholders engaged in the long value chain of agricultural commodities. The farmers can benefit from many buyers for their produce, enhancing their net income. Consumers can benefit from more alternatives for the same product with different prices and qualities, and bulk buyers and exporters can reduce their transaction costs by directly participating in the trade.

In subsequent years, E-NAM has emerged as a fruitful initiative for farmers, but little research has been conducted on E-NAM. Nair and Mehta (2020) found that E-NAM helps to achieve better price utilization through competitive bidding. Kumar et al. (2016) documented the historical evolution of e-NAM and its benefits for farmers and traders. Reddy and Mehjabeen (2019) documented the influence of ENAM on the amount accepted by farmers. Aggarwal et al. (2017) discovered that while India's e-National Agriculture Market in Karnataka has been consistently pushing through reforms, there remain significant challenges in the context of deeply entrenched relationships between farmers, traders, and commission agents.

3. Materials and Methods

3.1. Data Collection and Sample Characteristics

NCDEX is India's largest agricultural derivatives exchange, with a market share of 75% in agricultural derivative contracts for the financial year ending March 2021 (NCDEX 2022). The Exchange has maintained its leadership position since 2005 in the agricultural commodity derivatives market, in terms of average daily turnover value (ADTV). The Exchange has a diverse commodities portfolio totaling 23 (the most in the world) and includes commodities such as pulses, spices, and guar, which are not traded on any platforms in the global scenario but are economically relevant to India, constituting an important component of India's global trade. The 23 commodities are mainly categorized under the following heads, i.e., cereals and pulses (barley, chana, maize, wheat, moong, bajra, paddy basmati), fibers (kapas and 29 mm cotton), guar complex (guar seed and guar gum), oil and oil seeds (castor seed, refined castor oil, cottonseed oilcake, soybean, refined soya oil, mustard seed, crude palm oil, sesame oil, and hipro soybean meal), spices (turmeric, jeera, and coriander) and soft (gur and robusta cherry AB coffee). To analyze our study's long-run relationship and volatility, a sample of twelve commodities is selected out of 23. Selected commodities are traded on both the NCDEX and the E-NAM portal, with the NCDEX having a higher trading volume and the same trade center on both platforms. It mainly includes castor (Deesa in Gujarat), coriander (Kota in Rajasthan), soybean (Indore in MP), gwarseed (Jodhpur in Rajasthan), Turmeric (Nizamabad in Telangana), chana (Bikaner in Rajasthan), wheat (Kota in Rajasthan), barley (Jaipur in Rajasthan), jeera (Unjha in Gujarat), bajra (Jaipur in Rajasthan), moong (Merta-city in Rajasthan). The sample agricultural commodities futures prices and spot prices of NCDEX and spot prices of the E-NAM market were collected from the National Commodities and Derivatives Exchange (NCDEX 2022), the National Agriculture Market E-NAM 2022) and Agmarknet portal (Agmarknet 2022).

The study sample consists of daily data from April 2016 to December 2020. In the present study, as all the data involved is time-series, the first step in the analysis is to make visual plots of the data set using E-views software. The daily spot prices of the E-NAM market, the futures, and the spot prices of the NCDEX movement of twelve agricultural commodities are presented in Appendix A, Figure A1. From the plots, one can observe that all the selected agricultural commodities price series are moving in the same direction. If one price series shows a decreasing or increasing trend, will the other two follow suit? As a result, there is a possibility that the series will cointegrate in the long run. Before proceeding to the empirical analysis, the first step is to check the descriptive analysis of all the variables. The results of the descriptive statistics of all the variables for price series and differenced price series are expressed in Appendix A, Tables A1 and A2.

3.2. Johansen Cointegration Test and VEC Model

This study aims to examine the movement among spot prices at the National Agriculture Market (E-NAM), futures, and Spot prices at NCDEX in the Indian agricultural commodity market. The Johansen cointegration test is applied in the study to test the relationship in the long run between the E-NAM market, the futures, and the spot price of NCDEX. It validates the movement in the long run among more than two variables. If the long-run cointegration relationship among variables is established, the error correction term through the VECM model is estimated (Johansen 1988, 1995; Johansen and Juselius 1990; Zaidi and Rupeika-Apoga 2021). This term indicates the rate at which the long-run variables are adjusted by treating the three variables as both dependent and independent, resulting in a perception of the consistency of the long-run relationship between the variables.

The following Johansen Cointegration is estimated as:

$$\Delta \mathrm{X}t = \Pi\Delta\ \mathrm{X}t - 1 + \mathrm{et}, \tag{1}$$

where Xt is the 3×1 vector (Et, St, and Ft) of E-NAM, spot, and futures prices, respectively, Δ denotes the first difference operator, Π denotes the VECM specifications for long-run adjustment. Two likelihood ratio tests can be employed to identify the cointegration between the two series, i.e., trace statistics tests and max eigenvalue tests. The first statistic, λ trace statistics, tests whether the number of cointegrating vectors is zero or one, and the other λ max-eigenvalue tests whether a single cointegrating equation is sufficient or if two or more are required.

$$\lambda\mathrm{trace}(\mathrm{k}) = -T\sum\nolimits_{\mathrm{i=k+1}}^{\mathrm{n}} \ln(1-\lambda i) \tag{2}$$

$$\lambda\max(\mathrm{k}, \mathrm{k}+1) = -T\ln(1-\lambda\mathrm{k}+i), \tag{3}$$

The λ trace statistics test the null hypothesis that there are at most k cointegrating vectors against the alternative that the number of cointegrating vectors is greater than k. It means H0: K = K0 and H1: K > K0. The λ max tests the null hypothesis that the number of cointegrating vectors is k against the alternative of k + 1. It means H0: K = K0 and H1: K = K0 + 1. If the trace statistics and max-eigenvalues are greater than the critical value and significant, it means that the two series are cointegrated in the long run (Hansen and Johansen 1998).

Even if a long-run relationship exists between the different price series, there is a possibility of disequilibrium in the series. This disequilibrium shows the ability of the market to adjust to new information and hints at the leading position of the market. This model was used for measuring the error correction mechanism or speed of adjustment toward equilibrium, and it is estimated as follows:

$$\Delta E_t = \alpha_0 + \alpha_1 \Delta F_t + \alpha_2 \Delta S_t + \gamma ECT_{t-1} + e_t, \tag{4}$$

$$\Delta F_t = \beta_0 + \beta_1 \Delta E_t + \beta_2 \Delta S_t + \gamma ECT_{t-1} + e_t, \tag{5}$$

$$\Delta S_t = \mu_0 + \mu_1 \Delta E_t + \mu_2 \Delta F_t + \gamma ECT_{t-1} + e_t, \tag{6}$$

where E stands for the spot price for the E-NAM market, F stands for the futures price of NCDEX, S stands for the spot price of NCDEX and α, β, μ are the short-run coefficients, and γ represents the coefficient of ECT. Additionally, ECT_{t-1} represents the rate of long-run equilibrium at which the long-run variables are adjusted after some shock in the short run. On the other hand, if γ (coefficient value) is negative and statistically significant, then the correction or adjustment happens. In case it is positive, no correction or adjustment happens. This model shows the degree of disequilibrium from one period connected to the next and the magnitude of the adjustment that occurs in both markets in achieving equilibrium (Ali and Gupta 2011).

3.3. Engle Granger Causality Tests

After knowing the cointegration through Johansen's cointegration, and price discovery mechanism through the VECM model, the Granger Causality is estimated to show the lead-lag interaction between the series estimated (Johansen 1988, 1995; Johansen and Juselius 1990). These results might be interpreted as suggesting that information is incorporated slightly more quickly in one market as compared to other markets or that they move in a parallel direction. Also, the finding of the Granger causality does not mean that movements in one variable physically cause movements in another (Engle and Granger 1987). It doesn't mean that the price in one market changed as a direct result of, or because of, the movements in another market. Rather, causality simply implies a chronological ordering of movements in the series. It could be validly stated that movements in one market appear to lead those of other markets, and so on. In the Granger causality test, the null hypothesis is that the lagged x-values do not explain the variation in y. In other words, it is assumed that x(t) does not cause y(t). The Granger causality test for the two pairs of variables involves the estimation of the following VAR framework:

$$E_t = \check{S}_1 + \sum_{i=1}^{n} €_{1i} E_{t-i} + \sum_{j=1}^{m} £_{1j} F_{t-j} + \varepsilon_{1t} \tag{7}$$

$$F_t = \check{S}_2 + \sum_{i=1}^{n} €_{2i} E_{t-i} + \sum_{j=1}^{m} £_{2j} F_{t-j} + \varepsilon_{2t} \tag{8}$$

$$E_t = \check{S}_3 + \sum_{i=1}^{n} €_{3i} E_{t-i} + \sum_{j=1}^{m} £_{3j} S_{t-j} + \varepsilon_{3t} \tag{9}$$

$$St = \check{S}_4 + \sum_{i=1}^{n} €_{4i} E_{t-i} + \sum_{j=1}^{m} £_{4j} S_{t-j} + \varepsilon_{4t} \tag{10}$$

$$F_t = \check{S}_5 + \sum_{i=1}^{n} €_{5i} F_{t-i} + \sum_{j=1}^{m} £_{5j} S_{t-j} + \varepsilon_{5t} \tag{11}$$

$$S_t = \check{S}_6 + \sum_{i=1}^{n} €_{6i} S_{t-i} + \sum_{j=1}^{m} £_{6j} S_{t-j} + \varepsilon_{6t} \tag{12}$$

where E_t, F_t, and S_t are the price series of the spot market of the E-NAM, futures, and spot market of NCDEX respectively. To test the Granger causality in the VAR framework, alternative causal relations are likely to be found for each commodity:

(i) there is a unidirectional Granger causality from E_t to F_t if all €$_{2i}$ is not zero but all £$_{1j}$ are zero;
(ii) there is a unidirectional Granger causality from F_t to E_t if all £$_{1j}$ are not zero but all €$_{2i}$ is zero;
(iii) there is a bidirectional Granger causality from E_t to F_t if all £$_{1j}$, and €$_{2i}$ are not zero;
(iv) there is no Granger causality from E_t to F_t if all £$_{1j}$, and €$_{2i}$ are zero. Similarly, Granger causality for another group of variables has been estimated.

When only one variable causes the other, it is a unidirectional causality. When both variables cause each other, it is bidirectional causality. If no variables cause each other, there is no causal relationship.

3.4. Bivariate GARCH Model

Volatility is the variation or fluctuation in the market. Therefore, it is important to understand these variations to overcome the price risks. These variations can be considered as two terms, i.e., volatility persistence means variations or effects within the market, and volatility spillover means variations or effects between the markets. To estimate the changing variances, Robert F. Engle developed the ARCH model in 1982. The ARCH model says that the variance of the error term at time t (called conditional variance) depends on the squared error term from the previous period, i.e., ARCH:

$$h_t = b_0 + b_1\, u^2{}_{t-1} + b_2\, u^2{}_{t-2} + \ldots\ \ldots .+ b_q\, u^2{}_{t-q} + e_t \tag{13}$$

where h_t can be called the conditional variance of the error term at time t, which depends on the squared error term from previous periods. As h_t cannot be negative, the ARCH model valid provided $b_0 > 0$, and $b_q >= 0$ for q = 1, 2, 3 . . . .., q.

The major limitation of the ARCH model is that it is a short-term memory process in which the volatility or conditional variance is a function of the immediate past values of the squared term.

To estimate the volatility, the bivariate GARCH model developed by Bollerslev (1986) has been used, where he defines conditional variance as:

$$\text{GARCH(1,1)}: h_t = b_0 + ¥_1\, u^2{}_{t-1} + b_1\, h_{t-1}, \tag{14}$$

where the conditional variance (h_t) at time t depends both on the past values of the shocks captured by the lagged squared error term ($u^2{}_{t-1}$) and past values of itself (h_{t-1}). This is known as the variance equation, where

$$b_0 > 0,\ b_1 > 0,\ ¥_1 > 0 \text{ and } b_1 + ¥_1 < 1.$$

The degree of volatility persistence has been captured by the b_1 and ¥$_1$ coefficients. Here the absolute values of the coefficients were considered, which indicated the presence of volatility persistence. If the values were larger, it meant that the impact of an information shock took longer to decay. In other words, information arriving on a particular day was impacting that day's volatility as well as the following day's volatilities (Bollerslev and Engle 1993). Bivariate GARCH

$$h_t = b_0 + ¥_1\, u^2{}_{t-1} + b_1\, h_{t-1} + ¥_1\, u^2{}_{t-1(\text{another market})} \tag{15}$$

It says that today's volatility is dependent on yesterday's volatility in another market. Similarly, we analyze the volatility spillover effect of one market on another market by using a bivariate GARCH model. The volatility spillover effect is the extent to which the volatility in one market affects the other, and it is necessary to model the relationship between the volatilities of two markets (Singh et al. 2020). It can be estimated by creating a series of new residual terms, converting it into a squared residual term, and using it as a variance repressor to analyze its effect on the dependent variable.

4. Results

This study empirically examines the price discovery mechanism, lead-lag relationship, and volatility spillover of selected agricultural commodities between the E-NAM spot price and the NCDEX futures and spot prices.

The descriptive statistics tests show that, except for mustard and chana, all variables have skewness and kurtosis values ranging from −1 to +1, with a kurtosis value of around 3. The Jarque-Bera test indicates the non–normal behavior for all three price series by rejecting the null hypothesis. Before applying empirical tests, the unit root test was used to ensure that the variables were stationary. Unit root tests were employed to check the presence of unit root in the series. Therefore, the Augmented Dickey-Fuller (ADF) and Philip Perron tests are applied to test the unit roots in a time series. The results of the unit root test are shown in Table 1. The selected commodities are stationary at the first difference at the 5% level of significance. Level (0) depicts the original price series, and level (1) depicts the differenced price series.

Table 1. Result of Unit Root Test for all the selected commodities.

Commodity	Variables	Unit Root Test	ADF Test Level (0)	ADF Test Level (1)	PP Test Level (0)	PP Test Level (1)
Castor	E-NAM	T (*p*-value)	−2.08 (0.550)	−34.07 (0.0000 *)	−2.17 (0.5041)	−34.29 (0.0000 *)
	Futures	T (*p*-value)	−1.96 (0.6207)	−27.05 (0.0000 *)	−2.09 (0.5480)	−27.26 (0.0000 *)
	Spot	T (*p*-value)	−1.90 (0.6510)	−22.14 (0.0000 *)	−1.97 (0.6149)	−25.52 (0.0000 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary
Coriander	E-NAM	T (*p*-value)	−3.23 (0.078)	−27.90 (0.0000 *)	−4.37 (0.0024 *)	−62.77 (0.0000 *)
	Futures	T (*p*-value)	−2.23 (0.4716)	−31.48 (0.0000 *)	−2.02 (0.5850)	−31.44 (0.0000 *)
	Spot	T (*p*-value)	−1.54 (0.8129)	−30.28 (0.0000 *)	−1.62 (0.7838)	−30.68 (0.0000 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary
Soybean	E-NAM	T (*p*-value)	−2.66 (0.25)	−22.05 (0.0000 *)	−6.03 (0.0000 *)	−72.06 (0.0000 *)
	Futures	T (*p*-value)	−2.94 (0.1473)	−36.2 (0.0000 *)	−2.79 (0.1996)	−72.06 (0.0000 *)
	Spot	T (*p*-value)	−2.57 (0.2899)	−29.07 (0.0000 *)	−2.33 (0.4113)	−28.95 (0.0000 *)
	Inference		Non−stationary	Stationary	Non-stationary	Stationary
Gwar	E-NAM	T (*p*-value)	−2.78 (0.2025)	−31.16 (0.0000 *)	−3.46 (0.043 *)	−49.24 (0.0001 *)
	Futures	T (*p*-value)	−2.99 (0.1328)	−35.10 (0.0000 *)	−2.97 (0.1389)	−35.12 (0.0000 *)
	Spot	T (*p*-value)	−2.80 (0.1963)	−35.94 (0.0000 *)	−2.74 (0.2192)	−35.93 (0.0000 *)
	Inference		Non−stationary	Stationary	Non−stationary	Stationary
Turmeric	E-NAM	T (*p*-value)	−2.84 (0.1801)	−20.58 (0.0000 *)	6.310 (0.0001 *)	−52.93 (0.0000 *)
	Futures	T (*p*-value)	−3.20 (0.08)	−27.8 (0.0000 *)	−3.05 (0.1195)	−27.83 (0.0000 *)
	Spot	T (*p*-value)	−2.18 (0.4990)	−13.14 (0.0000 *)	−2.24 (0.4617)	−19.53 (0.0000 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary
Ghana	Futures	T (*p*-value)	−2.14 (0.521)	−26.05 (0.0000 *)	−2.37 (0.3927)	−26.18 (0.0000 *)
	Spot	T (*p*-value)	−2.09 (0.5451)	−28.02 (0.0000 *)	−2.27 (0.4465)	−28.07 (0.0000 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary
Wheat	E-NAM	T (*p*-value)	−1.35 (0.8733)	−24.29 (0.0000 *)	−1.65 (0.7696)	−36.46 (0.0000 *)
	Futures	T (*p*-value)	−1.55 (0.811)	−22.62 (0.0000 *)	−1.54 (0.7546)	−29.59 (0.0000 *)
	Spot	T (*p*-value)	−1.017 (0.9363)	−26.39 (0.0000 *)	−1.15 (0.9182)	−26.48 (0.0001 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary
Barley	E-NAM	T (*p*-value)	−1.19 (0.90)	−18.51 (0.0000 *)	−1.92 (0.6248)	−45.76 (0.0000 *)
	Futures	T (*p*-value)	−2.61 (0.27)	−24.66 (0.0000 *)	−2.63 (0.2647)	−42.58 (0.0000 *)
	Spot	T (*p*-value)	−1.38 (0.8643)	−9.36 (0.0000 *)	−1.26 (0.8960)	−27.26 (0.0000 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary

Table 1. *Cont.*

Commodity	Variables	Unit Root Test	ADF Test	ADF Test	PP Test	PP Test
			Level (0)	Level (1)	Level (0)	Level (1)
Mustard	E-NAM	T (*p*-value)	−1.49 (0.83)	−21.39 (0.0000 *)	−1.95 (0.6239)	−30.71 (0.0000 *)
	Futures	T (*p*-value)	−0.51 (0.9828)	−21.77 (0.0000 *)	−0.65 (0.9573)	−21.79 (0.0000 *)
	Spot	T (*p*-value)	0.287 (0.9985)	−21.54 (0.0000 *)	0.1554 (0.9997)	−21.58 (0.0000 *)
	Inference		Non-stationary	Stationary	Non-stationary	Stationary
Jeera	E-NAM	T (*p*-value)	−4.61(0.0011*)	−21.74 (0.0000 *)	−6.48 (0.0000 *)	−31.56 (0.0000 *)
	Futures	T (*p*-value)	−2.34 (0.40)	−22.71 (0.0000 *)	−2.32 (0.4206)	−22.75 (0.0000 *)
	Spot	T (*p*-value)	−1.68 (0.7550)	−19.85 (0.0000 *)	−1.77 (0.7144)	−19.93 (0.0000 *)
	Inference		Non−stationary	Stationary	Non−stationary	Stationary
Bajra	E-NAM	T (*p*-value)	−1.53 (0.8157)	−17.86 (0.000 *)	−1.47 (0.836)	−18.52 (0.000 *)
	Futures	T (*p*-value)	−1.19 (0.9077)	−13.72 (0.000 *)	−1.19 (0.907)	−13.78 (0.000 *)
	Spot	T (*p*-value)	−1.05 (0.9328)	−13.27 (0.000 *)	−1.12 (0.9022)	−13.39 (0.000 *)
	Inference		Non−stationary	Stationary	Non-stationary	Stationary
Moong	E−NAM	T (*p*-value)	−1.82 (0.6884)	−20.58 (0.000 *)	−3.96 (0.017 *)	−39.15 (0.000 *)
	Futures	T (*p*-value)	−1.84 (0.6789)	−16.56 (0.000 *)	−1.95 (0.621)	−16.51 (0.000 *)
	Spot	T (*p*-value)	−1.615 (0.7849)	−17.21 (0.000 *)	−1.70 (0.7454)	−17.22 (0.000 *)
	Inference		Non-stationary	Stationary	Non−stationary	Stationary

* *p*-value is less than 0.05.

4.1. Results of the Johansen Test and the VEC Model

As discussed in the methodology section, it is important to understand the relationship between the markets to understand the price discovery mechanism and volatility spillover. Johansen's cointegration test delivers the trace statistics and max-eigenvalue, which are greater than the critical value and significant. The results show that all three price series are cointegrated in the long run, and there is at least one cointegrating equation in the restricted VAR model (see Table 2).

Table 2. Results of Johansen Cointegration Tests.

Commodity	Hypothesized No. of CEs	Trace Statistics	Critical Value at 5%	Max Eigen Value	Critical Value at 5%	*p*-Value *
Castor	None *	124.0265	29.79	74.60938	21.13	0.0000 *
	At most 1 *	49.41709	15.49	45.63528	14.26	0.0000 *
	At most 2	3.781814	3.84	3.781814	3.84	0.0518
Coriander	None *	75.18175	29.79	45.31188	21.13	0.0000 *
	At most 1 *	29.86987	15.49	26.64745	14.26	0.0000 *
	At most 2	3.222423	3.84	3.222423	3.84	0.0726
Soybean	None *	96.94903	29.79	57.44351	21.13	0.0000 *
	At most 1 *	39.50553	15.49	38.16574	14.26	0.0000 *
	At most 2	1.339783	3.84	1.339783	3.84	0.2471
Gwar	None *	121.4787	29.79	83.58748	21.13	0.0000 *
	At most 1 *	37.89117	15.49	31.52028	14.26	0.0000 *
	At most 2	6.370894	3.84	6.370894	3.84	0.0506
Turmeric	None *	70.94496	29.79	36.09327	21.13	0.0000 *
	At most 1 *	34.85169	15.49	29.09227	14.26	0.0000 *
	At most 2	5.759413	3.84	5.759413	3.84	0.0564
Chana	None *	95.85518	29.79	57.41092	21.13	0.0000 *
	At most 1 *	38.44426	15.49	32.63860	14.26	0.0000 *
	At most 2	5.805662	3.84	5.805662	3.84	0.0560
Wheat	None *	45.42951	29.79	31.29639	21.13	0.0000 *
	At most 1 *	14.13312	15.49	10.50872	14.26	0.0494 *
	At most 2	3.624395	3.84	3.624395	3.84	0.0569

Table 2. *Cont.*

Commodity	Hypothesized No. of CEs	Trace Statistics	Critical Value at 5%	Max Eigen Value	Critical Value at 5%	*p*-Value *
Barley	None *	71.82386	29.79	51.52606	21.13	0.0000 *
	At most 1 *	20.29780	15.49	18.17957	14.26	0.0087 *
	At most 2	2.118228	3.84	2.118228	3.84	0.1456
Mustard	None *	66.56340	29.79	46.03735	21.13	0.0000 *
	At most 1 *	20.52605	15.49	19.95003	14.26	0.0000 *
	At most 2	0.576017	3.84	0.576017	3.84	0.4479
Jeera	None *	62.45950	29.79	52.84441	21.13	0.0000 *
	At most 1 *	9.615090	15.49	9.380898	14.26	0.0031 *
	At most 2	0.234192	3.84	0.234192	3.84	0.6684
Bajra	None *	32.36671	29.79	12.62417	21.13	0.0248 *
	At most 1 *	19.74255	15.49	11.21156	14.26	0.0108 *
	At most 2	8.530981	3.84	8.530981	3.84	0.0535
Moong	None *	65.62510	29.79	47.02224	21.13	0.0000 *
	At most 1 *	18.60286	15.49	14.74076	14.26	0.0164 *
	At most 2	3.862105	3.84	3.862105	3.84	0.0594

* *p*-value is less than 0.05.

After establishing the cointegration relationship, the error correction model is estimated. An error correction model enables one to study the short-run dynamics in the relationship between the variables. This model was first used by Sargan in 1964 and later popularized by Engle and Granger in 1987 (Engle and Granger 1987; Alogoskoufis and Smith 1991). This model assumes that a portion of disequilibrium in a given period will be corrected in the subsequent period. The results of the VECM model are presented in Table 3.

Table 3. Results of the VEC model.

Commodity	Dependent Variable	Error Correction Coefficient	Std. Error	T-Statistic
Castor	E-NAM	−0.048740	0.02450	−1.98950
	Futures	0.005682	0.02338	0.23405
	Spot	0.129795	0.01962	6.61636
Coriander	E-NAM	−0.095532	0.01764	−5.41716
	Futures	−0.011757	0.00852	−1.37999
	Spot	0.015249	0.00466	3.27106
Soybean	E-NAM	−0.248366	0.02970	−8.36216
	Futures	−0.015054	0.01357	−1.10950
	Spot	0.013019	0.01002	1.297872
Gwar	E-NAM	−0.130210	0.02720	−4.78667
	Futures	−0.039080	0.02184	−1.78909
	Spot	0.065805	0.01855	3.54678
Turmeric	E-NAM	−0.194862	0.03856	−5.05384
	Futures	0.002288	0.01834	0.12481
	Spot	0.029398	0.00808	3.63851
Chana	E-NAM	−0.391221	0.04464	−8.76407
	Futures	0.029205	0.02711	1.07729
	Spot	0.031477	0.02458	1.28043
Wheat	E-NAM	−0.050356	0.01163	−4.32967
	Futures	0.028298	0.01038	2.72721
	Spot	−0.028326	0.00620	−4.54678

Table 3. *Cont.*

Commodity	Dependent Variable	Error Correction Coefficient	Std. Error	T-Statistic
Barley	E-NAM	−0.022109	0.00679	−3.25835
	Futures	0.031967	0.00679	4.70942
	Spot	−0.009323	0.00193	−4.82108
Mustard	E-NAM	−0.140546	0.02736	−5.13626
	Futures	0.031214	0.01326	2.35485
	Spot	−0.015662	0.11551	−1.36072
Jeera	E-NAM	−0.004585	0.00680	−0.67388
	Futures	−0.002768	0.00665	−0.41605
	Spot	0.020885	0.00322	6.47976
Bajra	E-NAM	−0.191786	0.05052	−3.79620
	Futures	0.004707	0.02234	0.21067
	Spot	−0.008945	0.02558	−0.34971
Moong	E-NAM	0.004082	0.00656	0.62270
	Futures	0.014202	0.00372	3.81354
	Spot	−0.004032	0.00326	−1.23502

The results of the VECM model show that for most commodities, adjustments are being made from the NCDEX spot market and futures market to the E-NAM spot prices. The NCDEX spot and futures markets contribute to the price discovery mechanism. This means that whenever there is a market disequilibrium, both markets increase or decrease simultaneously to reach equilibrium. Thus, the equilibrium adjustment varies from commodity to commodity.

4.2. Results of Engle Granger Causality Tests

After knowing the cointegration through Johansen's cointegration and the price discovery mechanism through the VECM model, the Granger causality is estimated to show the lead-lag interaction between the series. The causal relationship provides the influential direction of the two markets. The results of Granger causality tests indicate that for most of the commodities futures and spot markets, NCDEX influences the spot prices of the newly introduced Indian spot market, i.e., E-NAM. Therefore, the futures and spot market of NCDEX lead the spot market of E-NAM. The different stakeholders can take advantage of it by getting the informational changes from the futures market and using them in the E-NAM spot market (Table 4).

Table 4. Results of Granger Causality Tests.

Commodities	Null Hypothesis	*p*-Value	Relationship	Direction
Castor	Futures do not Granger cause E-NAM price	0.0000 *	F causes E	Unidirectional
	E-NAM does not Granger cause Future price	0.5718	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0000 *	S causes E	Bidirectional
	E-NAM does not Granger cause Spot price	0.0328 *	E causes F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Unidirectional
	Spot does not Granger cause Future price	0.5264	S doesn't cause F	
Coriander	Futures do not Granger cause E-NAM price	0.8585	F doesn't cause E	No directional Relationship
	E-NAM does not Granger cause Future price	0.9095	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0000 *	S causes E	Bidirectional
	E-NAM does not Granger cause Spot price	0.0167 *	E causes F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Bidirectional
	Spot does not Granger cause Future price	0.0133 *	S causes F	

Table 4. *Cont.*

Commodities	Null Hypothesis	p-Value	Relationship	Direction
Soybean	Futures do not Granger cause E-NAM price	0.7511	F doesn't cause E	No directional Relationship
	E-NAM does not Granger cause Future price	0.4712	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0000 *	S causes E	Bidirectional
	E-NAM does not Granger cause Spot price	0.0042 *	E causes F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Bidirectional
	Spot does not Granger cause Future price	0.0000 *	S causes F	
Gwar	Futures do not Granger cause E-NAM price	0.0000 *	F causes E	Unidirectional
	E-NAM does not Granger cause Future price	0.3268	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0000 *	S causes E	Bidirectional
	E-NAM does not Granger cause Spot price	0.0113 *	E causes F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Bidirectional
	Spot does not Granger cause Future price	0.0005 *	S causes F	
Turmeric	Futures do not Granger cause E-NAM price	0.7203	F doesn't cause E	No direction
	E-NAM does not Granger cause Future price	0.8368	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0000 *	S causes E	Bidirectional
	E-NAM does not Granger cause Spot price	0.0004 * 44	E causes F	
	Futures do not Granger cause Spot price	0.0036 *	F causes S	Bidirectional
	Spot does not Granger cause Future price	0.0000 *	S causes F	
Chana	Futures do not Granger cause E-NAM price	0.0000 *	F causes E	Unidirectional
	E-NAM does not Granger cause Future price	0.2847	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0000 *	S causes E	Unidirectional
	E-NAM does not Granger cause Spot price	0.2134	E doesn't cause F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Unidirectional
	Spot does not Granger cause Future price	0.5357	S doesn't cause F	
Wheat	Futures do not Granger cause E-NAM price	0.0000 *	F causes E	Bidirectional
	E-NAM does not Granger cause Future price	0.0031 *	E causes F	
	Spot does not Granger cause E-NAM price	0.0001 *	S causes E	Unidirectional
	E-NAM does not Granger cause Spot price	0.4266	E doesn't cause F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Bidirectional
	Spot does not Granger cause Future price	0.0289 *	S causes F	
Barley	Futures do not Granger cause E-NAM price	0.1791	F doesn't cause E	No directional Relationship
	E-NAM does not Granger cause Future price	0.6221	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0025 *	S causes E	Unidirectional
	E-NAM does not Granger cause Spot price	0.1254′	S doesn't cause F	
	Futures do not Granger cause Spot price	0.0000 *	F doesn't cause S	Unidirectional
	Spot does not Granger cause Future price	0.0000 *	S causes F	
Mustard	Futures do not Granger cause E-NAM price	0.0064 *	F causes E	Bidirectional
	E-NAM does not Granger cause Future price	0.0227 *	E causes F	
	Spot does not Granger cause E-NAM price	0.8509	S doesn't cause F	No relation
	E-NAM does not Granger cause Spot price	0.6358	E doesn't cause F	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Unidirectional
	Spot does not Granger cause Future price	0.3385	S doesn't cause F	
Jeera	Futures do not Granger cause E-NAM price	0.0000 *	F causes E	Unidirectional
	E-NAM does not Granger cause Future price	0.3032	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.4272	S doesn't cause F	Unidirectional
	E-NAM does not Granger cause Spot price	0.0002 *	E causes S	
	Futures do not Granger cause Spot price	0.0000 *	F causes S	Unidirectional
	Spot does not Granger cause Future price	0.7670	S doesn't cause F	

Table 4. *Cont.*

Commodities	Null Hypothesis	*p*-Value	Relationship	Direction
Bajra	Futures do not Granger cause E-NAM price	0.0139 *	F causes E	Unidirectional
	E-NAM does not Granger cause Future price	0.6263	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.6405	S doesn't cause F	No relation
	E-NAM does not Granger cause Spot price	0.9778	E doesn't cause F	
	Futures do not Granger cause Spot price	0.2062	F doesn't cause S	No relation
	Spot does not Granger cause Future price	0.4804	S doesn't cause F	
Moong	Futures do not Granger cause E-NAM price	0.0064 *	F causes E	Unidirectional
	E-NAM does not Granger cause Future price	0.4569	E doesn't cause F	
	Spot does not Granger cause E-NAM price	0.0302 *	S causes E	Unidirectional
	E-NAM does not Granger cause Spot price	0.3940	E doesn't cause F	
	Futures do not Granger cause Spot price	0.0548	F doesn't cause S	Unidirectional
	Spot does not Granger cause Future price	0.0001 *	S causes F	

* *p*-value is less than 0.05.

4.3. Results of Volatility Tests

We used the bivariate GARCH model to analyze the volatility spillover from one market to another. To analyze the volatility spillover, first, we analyze the two basic conditions of the ARCH model, i.e., volatility clustering and the ARCH LM test. If the two basic conditions are fulfilled, then volatility persistence is analyzed, which depicts how much time the impact of an information shock will take to decay. Long-run cointegration causes the spillover effect. There is a possibility of volatility spillover from one segment to another for markets that have the association in the long run. Table 5 shows the results of the GARCH model for volatility spillover, which show that for most commodities, there is a volatility spillover effect from spot prices in the E-NAM market to futures and spot prices in the NCDEX. It means that the E-NAM market's spot price is more efficient than the other two markets. However, the magnitude of the NCDEX spot market volatility spillover effect is greater for certain commodities, such as castor, soybean, guar, and chana. As a result, the NCDEX spot market is efficient for these commodities. As a result, the various stakeholders trading in these commodities should be aware of market variations to mitigate price risks (Grima and Thalassinos 2020).

The result of volatility persistence reveals that for most commodities, the volatility persistence is greater than 90% except for jeera and bajra, which reveals that the impact of information shock will take longer to decay (see Table 5). However, in the case of barley and bajra, there is no volatility spillover between the three price series. In the case of bajra, it can be explained that it is an example of a Giffen good, which are typically inferior products preferred by low-income consumers, and their demand falls even when their prices fall (Aschonitis et al. 2016). Barley is traded by a small number of traders, and its prices rise only when demand rises (Chang et al. 2019). The overall results of the GARCH model conclude that the E-NAM market spot prices are an efficient market for various stakeholders, providing them with the option to avoid price risks in the market and a nationwide market to transact in.

Table 5. Results of Volatility Spillover Tests.

Commodity	Volatility Persistence	VarianceRegressor						
		SQDLE		SQDLF		SQDLS		
		F	S	E	S	E	F	Volatility Spillover (Market Efficiency)
Castor	>90%	1.11×10^{-5} (0.000 *)	2.17×10^{-5} (0.000 *)	4.53×10^{-5} (0.000 *)	3.32×10^{-5} (0.000 *)	3.82×10^{-5} (0.000 *)	7.74×10^{-5} (0.000 *)	Spot market of NCDEX
Coriander	>90%(E-NAM)	3.17×10^{-5} (0.000 *)	-3.65×10^{-5} (0.000 *)	-	-	-	-	Spot prices of the E-NAM market
Soybean	>90%	3.17×10^{-5} (0.000 *)	-3.65×10^{-5} (0.000 *)	0.0000 (1.000)	5.62×10^{-5} (0.000 *)	5.54×10^{-5} (0.000 *)	6.35×10^{-5} (0.000 *)	Spot market of NCDEX
Gwar	>90%	1.31×10^{-5} (0.000 *)	3.06×10^{-5} (0.000 *)	-6.43×10^{-5} (0.000 *)	8.14×10^{-5} (0.000*)	9.79×10^{-5} (0.000 *)	0.001 (0.000 *)	Spot market of NCDEX
Turmeric	>90%	2.71×10^{-5} (0.002 *)	2.55×10^{-5} (0.000 *)	-	-	-	-	Spot prices of the E-NAM market
Chana	>90%	2.52×10^{-5} (0.000 *)	4.08×10^{-5} (0.000 *)	8.84×10^{-5} (0.000 *)	0.000101 (0.000 *)	0.000105 (0.000 *)	0.000143 (0.000 *)	Spot market of NCDEX
Wheat	>90%(E-NAM) <90%(NCDEX)	2.71×10^{-5} (0.000 *)	0.0000 (1.000)	0.0000 (1.000)	0.0000 (1.000)	3.94×10^{-6} (0.000 *)	0.0000 (1.000)	Spot prices of the E-NAM market and NCDEX
Barley	<90%(E-NAM) >90% (Futures NCDEX)	-	0.0000 (1.000)	-	0.0000 (1.000)	-	-	No volatility Spillover
Mustard	>90%(E-NAM)	1.63×10^{-5} (0.000 *)	0.00134 (0.000 *)	-	-	-	-	Spot prices of the E-NAM market
Jeera	No volatility Persistence	-	-	-	-	-	-	No volatility Spillover
Bajra	No volatility Persistence	-	-	-	-	-	-	No volatility Spillover
Moong	>90%	0.185 (0.000 *)	3.46×10^{-5} (0.000 *)	-	-	-	-	Spot prices of the E-NAM market

* p-value is less than 0.05.

5. Discussion

According to Johansen's test results, all three price series are cointegrated in the long run, and the restricted VAR model contains at least one cointegrating equation. Our findings are consistent with Srinivasan's (2011) study, which found long-term equilibrium relationships between futures prices and their underlying spot prices for four MCX futures and spot indices representing relevant sectors such as agriculture (MCXAGRI), energy (MCXENERGY), metals (MCXMETAL), and the composite index of metals, energy, and agro-commodities (MCXCOMDEX).

Our findings call into question the commonly held belief in commodity markets that the futures market dominates the price discovery process. For example, Kim and Lim (2019) found that price discovery exists in the entire steel futures market and that futures prices in all items are mainly leading spot prices through permanent-transitory and information sharing using a vector error correction model and GARCH in Chinese spot and futures markets. From 2008 to 2012 Joseph et al. (2014) investigated the direction, strength, and extent of the causal relationship between futures and spot prices in Indian commodity markets for daily futures and spot price series on eight commodities. They discovered that the futures market has a strong price discovery function in all of the commodities studied, indicating the efficiency of the Indian commodity futures market.

This study shows that the futures market does not completely dominate price discovery, and the results are novel and consistent with the Narayan and Sharma (2018) study, which found that the spot market dominates price discovery in nine commodities. Dolatabadi et al. (2015) found slightly more evidence of price discovery in the spot market than the non-fractional model results. According to Srinivasan (2011), the VECM demonstrates that commodity spot markets play a dominant role and serve as an effective price discovery vehicle, implying that there is a flow of information from spot to futures commodity markets. The findings of the causal relationship provide the influential direction of the two markets. It indicates that the futures and spot markets of NCDEX lead the newly introduced Indian spot market, i.e., E-NAM which helps the different stakeholders to hedge their risks and ultimately reduces the arbitrage opportunities in the market. Our findings are consistent with those of Srinivasan (2011), who discovered that, while bidirectional volatility spillover persists, volatility spillovers from spot to futures markets dominate in all Multi Commodity Exchange of India (MCX) commodity markets.

Our findings concluded that the newly introduced Indian spot market, i.e., E-NAM helps in the price discovery mechanism for some commodities, and all three series are cointegrated in the long run. Different stakeholders, including farmers, traders, and hedgers, can take advantage of this. In earlier times, farmers were not getting pricing information, so they sold their commodities immediately at whatever prices they found, but after E-NAM, they can sell their goods at higher prices in the future by taking advantage of Electronic National Warehouse Receipts. Secondly, due to real-time price discovery, the manipulation activities have been reduced, and the farmers are getting direct payment into their accounts, which makes them independent. Also, the farmers can take a loan after storing their goods in a warehouse and pay it back after selling them later on. Through this, there may be a change in price levels, as goods are available for more time in the market. Thus, after the newly introduced Indian spot market was introduced, the farmers learned of the crop pattern, and they took advantage of higher prices in the future to overcome their price risk.

In addition to this, the different traders and hedgers can also take advantage of the price discovery mechanism by getting the price information from both the E-NAM market and futures market and offset their risk accordingly. Since the futures and spot markets of NCDEX lead the E-NAM spot market, therefore the different stakeholders came to know of the demand and supply conditions in the market. Since there is a volatility spillover effect for most of the commodities, therefore the investors should be aware of the variations in the E-NAM spot market to deal in the commodity futures exchange.

According to the study's findings, the NCDEX spot and futures market continues to dominate in the price discovery mechanism and lead the market. On the other hand, spot prices in the E-NAM market are useful for various stakeholders in bringing transparency to the agricultural commodity market. However, various stakeholders, particularly farmers, can access markets through warehouse-based sales, reducing the need to transport their produce to the grain market. Furthermore, the study shows that different buyers and sellers can transact in multiple markets while not being in the same location. More buyers can bid on a specific lot using the E-NAM platform. The dispersed group of online buyers bidding anonymously reduces traders' opportunities for collusion. Different traders have access to a large national market for secondary trading. It eventually reduces market arbitrage opportunities.

The current study has practical implications for various stakeholders, including farmers, traders, and investors. In the long run, all three markets are cointegrated. The E-NAM market allows Indian farmers to learn about the prices of various commodities and thus take advantage of price signals to adjust their prices. This combination of risk reduction and assured profit will be enticing, potentially bringing the farming community and the futures market together on a single platform. The findings of our study provide evidence of market integration in India. Our findings suggest that the newly introduced Indian spot market, i.e., E-NAM promotes integrity in the agricultural commodity market by streamlining the procedures across the different integrated markets, removing information asymmetry between buyers and sellers, and promoting real-time price discovery based on actual demand and supply. Hence, this has the potential to entice more farmers to participate in futures trading. This is also evident from the fact that over one trillion rupees in payment transactions have been processed through the E-NAM platform, allowing Indian farmers to become self-sufficient. According to the study, E-NAM helps to increase transparency in agricultural marketing, but more technological literacy and training are required to reap the full benefits of this platform. The Indian government should encourage all stakeholders, particularly farmers, to use this digital platform. To increase the popularity of the E-NAM and combat client resistance, the government should establish specific policies related to digital crimes and proper and clear arrangements for the remedy or compensation of wrongdoing or grievances (Kaur et al. 2021). Since the onset of the COVID-19 pandemic, businesses have dramatically increased the use of digital solutions and online commerce, and this trend is expected to continue (Rupeika-Apoga et al. 2022; Rupeika-Apoga and Petrovska 2022). Finally, E-NAM will alter the nature of agriculture in a developing country such as India, ensuring a higher return and income for all stakeholders. Our study also contributes towards the law of one price which states that the price of an identical commodity will have the same price globally, regardless of location and there is no price manipulation between buyers and sellers, which mostly takes place in earlier times due to the lack of pricing information. After the introduction of the newly introduced Indian spot market, i.e., E-NAM farmers are not compelled to sell their commodities immediately having huge price variations in the different markets. So, it helps to reduce the arbitrage opportunities in the market and contributes to the law of one piece across different markets.

Our study is not without limitations. Our sample spans the years 2016 to 2020, preventing us from examining the COVID-19 effect. Furthermore, if intraday data were available, we could investigate the research topic using other methods. Future research could focus on various commodities traded on domestic and international agricultural commodity markets. This would allow the study's findings to be generalized to other countries.

Author Contributions: Conceptualization, M.G., S.S., K.S., R.R.-A. and S.G.; methodology, M.G., S.S., K.S. and S.G.; validation, M.G., S.S., K.S., R.R.-A. and S.G.; formal analysis, M.G., S.S., K.S., R.R.-A. and S.G.; data curation, M.G., S.S., K.S. and S.G.; writing—original draft preparation, M.G., S.S., K.S., R.R.-A. and S.G.; writing—review and editing, M.G., S.S., K.S., R.R.-A. and S.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is available from authors upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

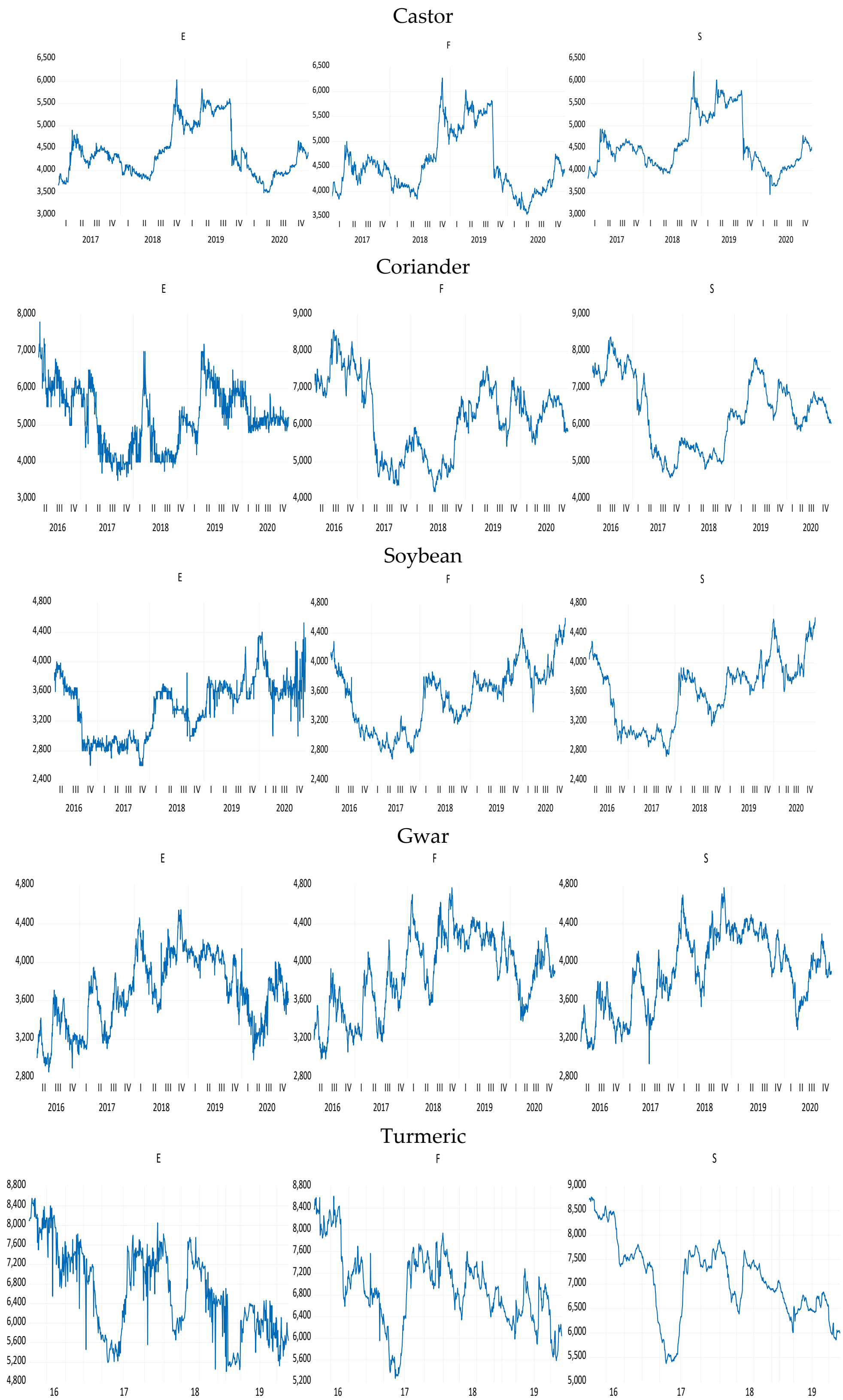

Figure A1. *Cont.*

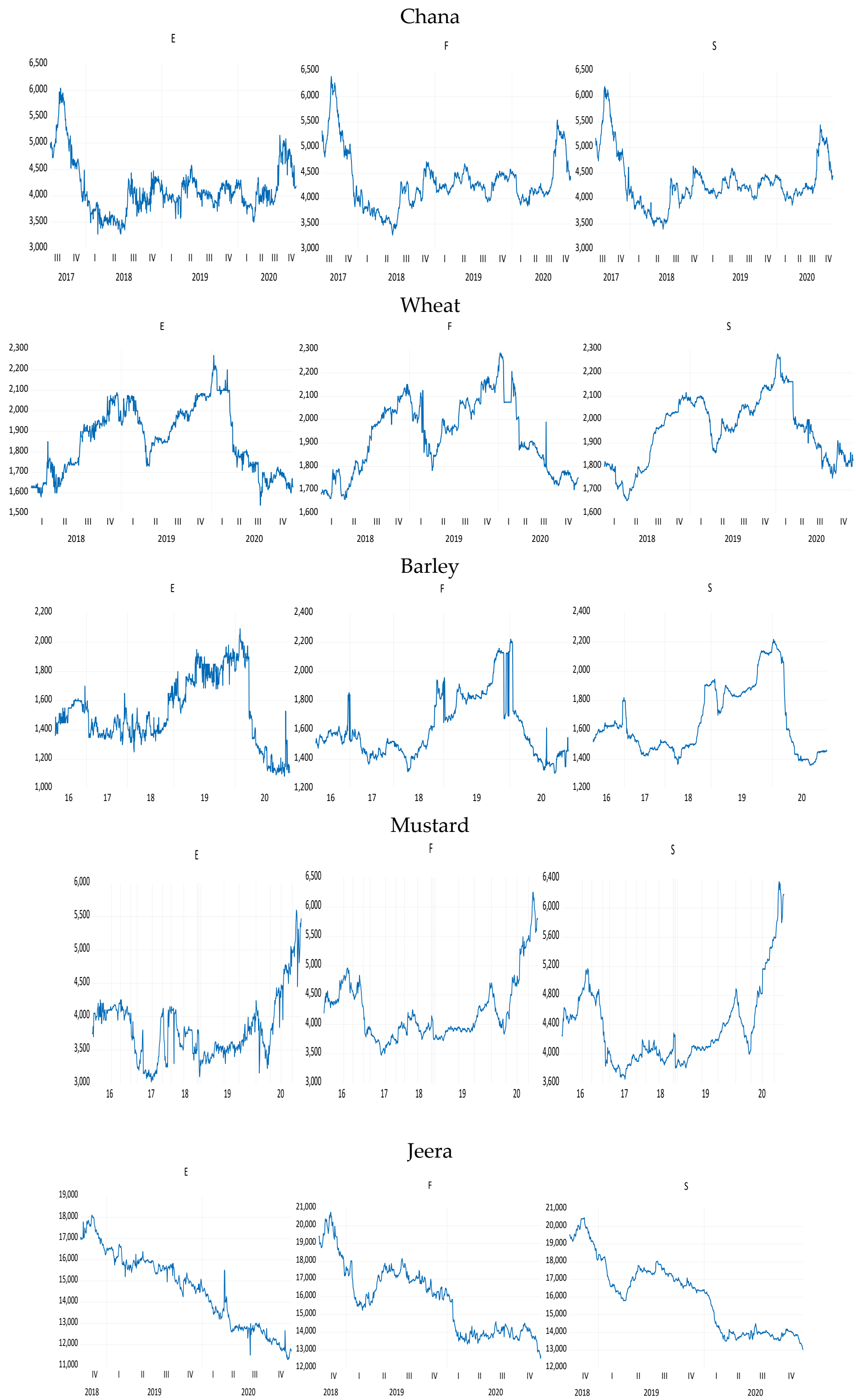

Figure A1. *Cont.*

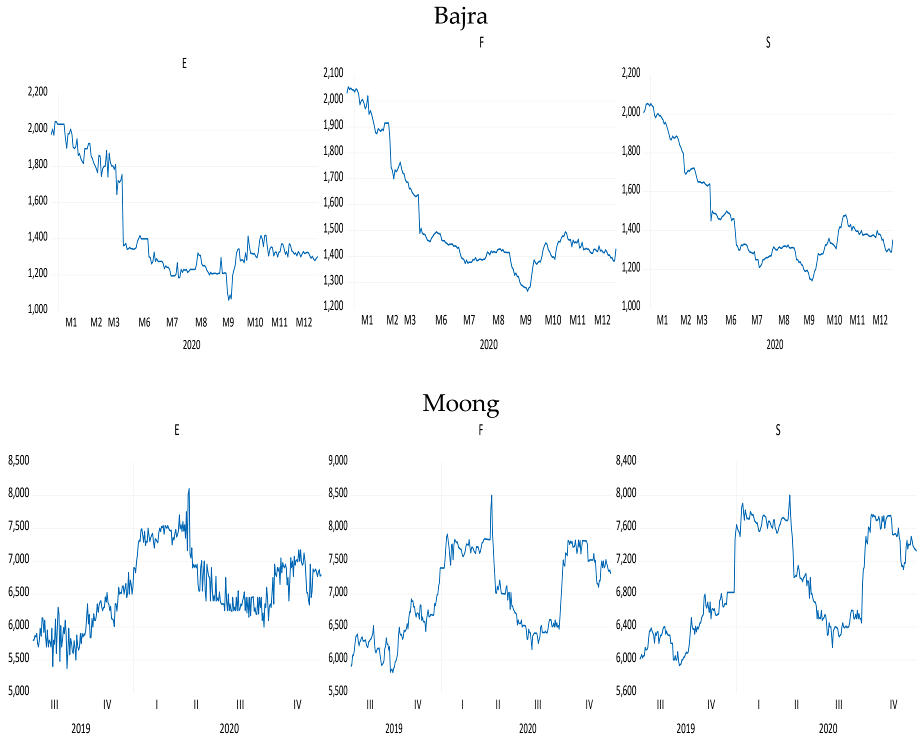

Figure A1. The daily spot prices of the E-NAM market, the future, and the spot prices of the NCDEX.

Table A1. Descriptive Statistics of price series of all the commodities.

Commodity	Mean	Std. Dev	Skewness	Kurtosis	J.Bera	Prob	Obs
Castor–E	4412.3	564.59	0.69	2.44	88.59	0.00 *	938
Castor–F	4548.5	605.11	0.73	2.50	93.70	0.00 *	938
Castor–S	4568.6	581.24	0.71	2.48	90.48	0.00 *	938
Coriander–E	5221.8	821.97	0.07	2.26	26.54	0.00 *	1122
Coriander–F	6210.8	1022.0	−0.03	2.09	38.82	0.00 *	1122
Coriander−S	6342.5	963.87	−0.007	1.88	57.91	0.00 *	1122
Soybean−E	3389.6	390.45	−0.03	2.25	26.04	0.00 *	1105
Soybean−F	3538.1	431.15	0.02	2.18	30.97	0.00 *	1105
Soybean−S	3606.2	440.40	−0.05	2.11	37.04	0.00 *	1105
Gwar–E	3682.2	368.00	−0.08	2.09	39.80	0.00 *	1134
Gwar–F	3881.4	402.48	−0.23	2.07	50.99	0.00 *	1134
Gwar−S	3903.6	388.81	−0.20	2.07	48.50	0.00 *	1134
Turmeric–E	6654.9	886.05	0.05	1.94	29.04	0.00 *	620
Turmeric–F	6931.2	703.63	0.04	2.83	0.84	0.65	620
Turmeric−S	7084.9	777.10	−0.05	2.61	4.24	0.11	620
Chana–E	4138.4	497.71	1.34	5.17	392.3	0.00 *	787
Chana–F	4340.5	548.71	1.20	4.83	299.2	0.00 *	787
Chana−S	4323.2	509.38	1.28	5.09	360.7	0.00 *	787
Wheat–E	1860.6	162.78	0.09	1.82	38.8	0.00 *	698
Wheat–F	1930.9	154.25	0.03	1.91	34.27	0.00 *	698
Wheat −S	1954.0	141.30	−0.10	2.19	20.27	0.00 *	698
Barley–E	1526.0	232.40	0.24	2.22	27.32	0.00 *	785
Barley–F	1615.1	212.21	0.93	3.12	114.0	0.00 *	785
Barley−S	1664.1	233.87	0.72	2.35	82.13	0.00 *	785
Mustard–E	3817.4	480.79	1.02	4.31	130.2	0.00 *	525
Mustard–F	4235.4	531.3	1.41	4.88	252.7	0.00 *	525
Mustard−S	4371.2	545.4	1.38	4.79	237.8	0.00 *	525
Jeera–E	14,632	1745.4	−0.10	1.89	28.59	0.00 *	539
Jeera–F	15,875	1921.6	0.40	2.27	26.34	0.00 *	539
Jeera–S	16,095	1994.1	0.25	1.99	28.51	0.00 *	539
Bajra–E	1448.6	274.01	0.99	2.42	37.08	0.00 *	208
Bajra–F	1534.4	215.13	1.25	3.19	54.63	0.00 *	208
Bajra–S	1471.9	247.83	1.05	2.87	38.48	0.00 *	208
Moong–E	6575.8	556.1	0.20	2.30	8.75	0.01 *	324
Moong–F	6956.3	623.2	0.10	1.67	24.2	0.00 *	324
Moong–S	6935.3	605.0	0.10	1.49	24.2	0.00 *	324

* p-value is less than 0.05.

Table A2. Descriptive statistics for differenced series.

Commodity	Mean	Std. Dev	Skewness	Kurtosisis	J.Bera	Prob	Obs
Castor–DE	0.77	76.71	−0.95	16.4	7186.0	0.00 *	937
Castor–DF	0.56	64.17	−0.16	5.62	273.5	0.00 *	937
Castor–DS	0.73	61.2	−0.36	17.4	8215.7	0.00 *	937
Coriander–DE	−1.47	278.28	0.09	5.50	293.73	0.00 *	1121
Coriander–DF	−1.10	120.96	−0.15	11.2	3199.2	0.00 *	1121
Coriander−DS	−1.24	68.91	−1.03	14.3	6171.4	0.00 *	1121
Soybean−DE	0.22	124.08	0.02	15.9	7695.7	0.00 *	1104
Soybean−DF	0.45	49.65	−0.18	10.94	2906.68	0.00 *	1104
Soybean−DS	0.50	38.18	0.09	9.11	1719.65	0.00 *	1104
Gwar–DE	0.53	86.09	0.14	7.31	883.52	0.00 *	1133
Gwar–DF	0.62	60.03	0.16	4.28	83.16	0.00 *	1133
Gwar−DS	0.63	54.61	−0.005	9.13	83.16	0.00 *	1133
Turmeric–DE	−3.95	361.21	−0.006	10.22	1344.64	0.00 *	619
Turmeric–DF	−3.78	149.62	0.39	13.6	2948.63	0.00 *	619
Turmeric−DS	−4.41	66.06	1.08	12.7	2576.39	0.00 *	619
Chana–DE	−1.02	131.63	0.08	5.59	221.48	0.00 *	786
Chana–DF	−1.20	68.16	−0.15	6.25	349.94	0.00 *	786
Chana−DS	−0.94	65.07	0.58	11.22	2262.61	0.00 *	786
Wheat–DE	0.007	27.31	−0.39	7.51	609.2	0.00 *	697
Wheat–DF	0.10	23.03	−0.67	30.05	21315.95	0.00 *	697
Wheat−DS	0.03	13.67	−1.09	19.06	7631.87	0.00 *	697
Barley–DE	−0.32	54.37	−0.20	11.9	2599.55	0.00 *	784
Barley–DF	−0.06	53.76	−1.11	47.14	63825.4	0.00 *	784
Barley−DS	−0.08	14.93	0.22	35.97	35529.4	0.00 *	784
Mustard–DE	3.27	144.46	−0.88	14.52	2967.72	0.00 *	524
Mustard–DF	3.04	66.51	0.26	8.49	665.47	0.00 *	524
Mustard−DS	3.69	58.46	−0.73	18.6	5371.8	0.00 *	524
Jeera–DE	−9.94	207.42	1.48	28.50	14783.9	0.00 *	538
Jeera–DF	−12.5	189.85	−0.64	7.04	405.14	0.00 *	538
Jeera–DS	−12.05	100.86	0.66	7.49	493.37	0.00 *	538
Bajra–DE	−3.27	48.43	−2.52	23.41	3813.55	0.00 *	207
Bajra–DF	−2.91	19.94	−2.78	20.92	3038.19	0.00 *	207
Bajra–DS	−3.17	22.76	−2.92	25.52	4672.13	0.00 *	207
Moong–DE	3.06	216.93	−0.18	5.12	62.78	0.00 *	323
Moong–DF	4.36	103.98	−0.32	7.23	246.96	0.00 *	323
Moong–DS	4.06	89.22	1.37	12.8	1413.86	0.00 *	323

* *p*-value is less than 0.05.

References

Abraham, Rose Mary K. 2022. Financialisation of Commodity Markets: Evidence from India. *Margin: The Journal of Applied Economic Research* 16: 106–31. [CrossRef]

Aggarwal, Nidhi, Sargam Jain, and Sudha Narayanan. 2017. The Long Road to Transformation of Agricultural Markets in India. *Economic and Political Weekly* 52: 47–55.

Agmarknet. 2022. Agriculture Marketing. Available online: http://agmarknet.gov.in/Default.aspx (accessed on 14 September 2022).

Ali, Jabir, and Kriti Bardhan Gupta. 2011. Efficiency in Agricultural Commodity Futures Markets in India: Evidence from Cointegration and Causality Tests. *Agricultural Finance Review* 71: 162–78. [CrossRef]

Alogoskoufis, George, and Ron Smith. 1991. On error correction models: Specification, interpretation, estimation. *Journal of Economic Surveys* 5: 97–128. [CrossRef]

Aschonitis, V. G., M. Gaglio, G. Castaldelli, and E. A. Fano. 2016. Criticism on Elasticity-Sensitivity Coefficient for Assessing the Robustness and Sensitivity of Ecosystem Services Values. *Ecosystem Services* 20: 66–68. [CrossRef]

Basavaraj, C. S., and G. Prahlad Chowdri. 2013. Price Discovery in Indian Commodity Market A Study of Red Chilli Futures. *Sumedha Journal of Management* 2: 30–37.

Basu, Sankarshan. 2020. Spot and Futures Markets–Scope for Integration. *IIMB Management Review* 32: 336–45. [CrossRef]

Bezzina, Frank, and Simon Grima. 2012. Exploring factors affecting the proper use of derivatives: An empirical study with active users and controllers of derivatives. *Managerial Finance* 38: 414–35. [CrossRef]

Bhatnagar, Mukul, Ercan Özen, Sanjay Taneja, Simon Grima, and Ramona Rupeika-Apoga. 2022. The Dynamic Connectedness between Risk and Return in the Fintech Market of India: Evidence Using the GARCH-M Approach. *Risks* 10: 209. [CrossRef]

Bollerslev, Tim. 1986. Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics* 31: 307–27. [CrossRef]

Bollerslev, Tim, and Robert F. Engle. 1993. Common Persistence in Conditional Variances. *Econometrica* 61: 167. [CrossRef]

Chang, Chia-Lin, Chia-Ping Liu, and Michael McAleer. 2019. Volatility Spillovers for Spot, Futures, and ETF Prices in Agriculture and Energy. *Energy Economics* 81: 779–92. [CrossRef]

Chari, Varadarajan, and Lawrence Christiano. 2017. *Financialization in Commodity Markets*. NBER Working Paper 23766. Cambridge: National Bureau of Economic Research, Inc. Available online: https://econpapers.repec.org/paper/nbrnberwo/23766.htm (accessed on 12 December 2022).

Cheng, Ing-Haw, and Wei Xiong. 2014. Financialization of Commodity Markets. *Annual Review of Financial Economics* 6: 419–41. [CrossRef]

Da Fonseca, José, and Yahua Xu. 2019. Variance and Skew Risk Premiums for the Volatility Market: The VIX Evidence. *Journal of Futures Markets* 39: 302–21. [CrossRef]

Ding, Shusheng, Tianxiang Cui, Dandan Zheng, and Min Du. 2021. The Effects of Commodity Financialization on Commodity Market Volatility. *Resources Policy* 73: 102220. [CrossRef]

Dolatabadi, Sepideh, Morten Ørregaard Nielsen, and Ke Xu. 2015. A Fractionally Cointegrated VAR Analysis of Price Discovery in Commodity Futures Markets: Fractionally Cointegrated VAR Analysis of Price Discovery. *Journal of Futures Markets* 35: 339–56. [CrossRef]

E-NAM. 2022. Electronic National Agriculture Market. Available online: https://www.enam.gov.in/web/ (accessed on 24 September 2022).

Engle, Robert F., and C. W. J. Granger. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica* 55: 251. [CrossRef]

Grima, Simon. 2012. The Current Financial Crisis and Derivative Misuse. *Journal of Social Sciences Research* 1: 265–76.

Grima, Simon, and Eleftherios Thalassinos. 2020. *Financial Derivatives: A Blessing or a Curse?* Edited by R. Dalli Gonzi and I. Thalassinos. Bingley: Emerald Group Publishing Limited, chp. 2. pp. 28–45.

Hansen, Peter Reinhard, and Søren Johansen. 1998. *Workbook on Cointegration*. Workbook edition. Oxford and New York: Oxford University Press.

IMF. 2023. World Economic Outlook. Available online: https://www.imf.org/external/datamapper/NGDPD@WEO (accessed on 12 September 2022).

Johansen, Søren. 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* 12: 231–54. [CrossRef]

Johansen, Søren. 1995. *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 1st ed. Oxford: Oxford University Press. [CrossRef]

Johansen, Søren, and Katarina Juselius. 1990. Maximum likelihood estimation and inference on cointegration–with applications to the demand for money: Inference on cointegration. *Oxford Bulletin of Economics and Statistics* 52: 169–210. [CrossRef]

Joseph, Anto, Garima Sisodia, and Aviral Kumar Tiwari. 2014. A Frequency Domain Causality Investigation between Futures and Spot Prices of Indian Commodity Markets. *Economic Modelling* 40: 250–58. [CrossRef]

Kaur, Balijinder, Sood Kiran, Simon Grima, and Ramona Rupeika-Apoga. 2021. Digital Banking in Northern India: The Risks on Customer Satisfaction. *Risks* 9: 209. [CrossRef]

Kim, Kyoungsu, and Seok Lim. 2019. Price Discovery and Volatility Spillover in Spot and Futures Markets: Evidence from Steel-Related Commodities in China. *Applied Economics Letters* 26: 351–57. [CrossRef]

Kumar, Neeray, Amit Kumar, and Sachin Tyagi. 2016. ENAM: Connecting Farmers and Traders. *Rashtriya Krishi* 11: 61–62.

Naik, Gopal, and Sudhir Kumar Jain. 2002. Indian Agricultural Commodity Futures Markets: A Performance Survey. *Economic and Political Weekly* 37: 3161–73.

Nair, Devipriya, and Shivani Mehta. 2020. E-NAM: An Impact Study on Doubling Farmers Income. *Sustainable Humanosphere* 16: 1765–81.

Narayan, Paresh Kumar, and Susan Sunila Sharma. 2018. An Analysis of Time-Varying Commodity Market Price Discovery. *International Review of Financial Analysis* 57: 122–33. [CrossRef]

NCDEX. 2022. National Commodities and Derivatives Exchange. Available online: https://ncdex.com/ (accessed on 9 September 2022).

Rajib, Prabina. 2015. Indian Agricultural Commodity Derivatives Market–In Conversation with S Sivakumar, Divisional Chief Executive, Agri Business Division, ITC Ltd. *IIMB Management Review* 27: 118–28. [CrossRef]

Reddy, A. Amarender, and Mehjabeen. 2019. Electronic National Agricultural Markets, Impacts, Problems and Way Forward. *IIM Kozhikode Society & Management Review* 8: 143–55. [CrossRef]

Rout, Bhabani Sankar, Nupur Moni Das, and K. Chandrasekhara Rao. 2021a. Functional Effectiveness of Commodity Futures Market: A Comparative Assessment of Agricultural and Metal Commodities. *Paradigm* 25: 42–60. [CrossRef]

Rout, Bhabani Sankar, Nupur Moni Das, and K. Chandrasekhara Rao. 2021b. Competence and Efficacy of Commodity Futures Market: Dissection of Price Discovery, Volatility, and Hedging. *IIMB Management Review* 33: 146–55. [CrossRef]

Rupeika-Apoga, Ramona, and Kristine Petrovska. 2022. Barriers to Sustainable Digital Transformation in Micro, Small, and Medium-Sized Enterprises. *Sustainability* 14: 13558. [CrossRef]

Rupeika-Apoga, Ramona, Kristine Petrovska, and Larisa Bule. 2022. The Effect of Digital Orientation and Digital Capability on Digital Transformation of SMEs during the COVID-19 Pandemic. *Journal of Theoretical and Applied Electronic Commerce Research* 17: 669–85. [CrossRef]

SAMCO. 2022. Understand the History of Commodity Trading in India. Samco. Available online: https://www.samco.in/history-of-commodity-trading-in-india (accessed on 3 August 2022).

Sehgal, Sanjay, Namita Rajput, and Rajeev Kumar Dua. 2012. Price Discovery in Indian Agricultural Commodity Markets. *International Journal of Accounting and Financial Reporting* 2: 34. [CrossRef]

Sharma, Tanushree. 2015. An Empirical Analysis of Commodity Future Market in India. *International Journal of Engineering Technology, Management and Applied Sciences* 3: 19. Available online: https://www.academia.edu/12825115/An_Empirical_Analysis_of_Commodity_Future_Market_in_India (accessed on 12 September 2022).

Singh, Sanjay Kumar, Mukesh Kumar Jain, and Shoeba. 2020. Information Spillover in Indian Agricultural Commodities Market. *Asia-Pacific Journal of Management Research and Innovation* 16: 179–87. [CrossRef]

Srinivasan, Palaniyappan. 2011. Price Discovery and Volatility Spillovers in Indian Spot-Futures Commodity Market. *He IUP Journal of Behavioral Finance* 9: 70–85.

USDA. 2022. National Agricultural Statistics Service (NASS). Available online: https://www.nass.usda.gov/Publications/Calendar/reports_by_date.php?month=11 (accessed on 22 September 2022).

WFE. 2023. Reforms to Put the Indian Commodity Market in Orbit | The World Federation of Exchanges. Available online: https://focus.world-exchanges.org/articles/reforms-put-indian-commodity-markets-next-orbit (accessed on 15 September 2022).

Zaidi, Syeda Hina, and Ramona Rupeika-Apoga. 2021. Liquidity Synchronization, Its Determinants and Outcomes under Economic Growth Volatility: Evidence from Emerging Asian Economies. *Risks* 9: 43. [CrossRef]