Arbitrage, Error Correction, and Causality : Case of Highly Traded Agricultural Commodities in India

** Ruchika Kaura*
*** Nawal Kishor*
**** Namita Rajput*

Abstract

India is an agriculture - dominated country and futures trading in commodities has emerged as a mode to protect the farmers and traders from price fluctuations and to relieve them from the trouble of maintaining stocks. However, mispricing between futures and spot markets of commodities has persisted from time to time due to market inefficiencies, which are taken care by rational investors and arbitrageurs present in the market. The study aimed to examine the speed, magnitude, and significance of error correction in the presence of arbitrage opportunities and the causality relationship between the spot and the futures markets of selected highly traded agricultural commodities namely, cardamom, cotton, crude palm oil, and mentha oil traded on the leading commodity exchange of India, that is, MCX. The results of vector error correction model provided empirical evidence that there existed significant error correction and causality between the futures and spot prices of selected agricultural commodities in India. Even though the futures and spot prices of these commodities were co-integrated in the long run, but in the short-run, there arose a disequilibrium resulting in exploitable arbitrage opportunities. Trading by the arbitrageurs in these markets leads to significant error correction, thereby bringing the markets into equilibrium again. Also, bi-directional causality between the markets was observed for all commodities with futures markets Granger causing spot markets more strongly. The knowledge of existence of arbitrage opportunities and information about the error correction is valuable for farmers, traders, and organizations occupied in producing, processing, and marketing of commodities to hedge their market risk and gain profits.

Keywords : **agricultural commodities, arbitrage, error correction, causality, commodity market, VECM, Granger causality test**

JEL Codes : C10, C32, G13, G14

Paper Submission Date : August 20, 2018 ; Paper sent back for Revision : July 18, 2019 ; Paper Acceptance Date : July 30, 2019

An arbitrage is the simultaneous trading of an asset or financial instrument in different markets or different forms for exploiting the price difference to make a profit. Classical theories, that is, law of one price and efficient market hypothesis state that if the market is efficient, there must be a single price of one commodity or asset regardless of where it is traded. However, in reality, mispricing of assets persists from time to time due to market inefficiencies which are taken care of by rational investors and arbitrageurs present in the market. Arbitrageurs undertake trading actions in these markets to grab the profit and drive the misplaced price

* *Assistant Professor,* Atma Ram Sanatan Dharma College, University of Delhi, Dhaula Kuan, New Delhi - 110 021. (Email : ruchikakaura@gmail.com) ; ORCID ID : 0000-0001-9686-9728
** *Professor,* School of Management Studies, Indira Gandhi National Open University, Maidan Garhi, New Delhi - 11 0 068. (Email : nkishor@ignou.ac.in) ; ORCID ID : 0000-0003-4271-8208
*** *Principal (OSD),* Sri Aurobindo College (Evening), University of Delhi, Malviya Nagar, New Delhi - 110 017. (Email : namitarajput27@gmail.com) ; ORCID ID : 0000-0001-7978-0959

DOI : 10.17010/ijf/2019/v13i9/147095

back to the original level. The presence of noise in the pricing system on futures and spot markets creates a difference in expected return, providing motivation to the traders for gathering and using the private information, thereby supporting the futures market's information exchange role apart from its well-accepted hedging and risk allocation role. A strand of literature exists that provides theoretical and empirical support to the acceptable opinion that well-structured futures markets hold important information for the potential changes in spot market prices in the short-run, however, in the long-run, both futures and spot markets prices follow strong and steady co-movements. Deviation of futures and spot price series from each other in the short-run offers arbitrage opportunities which are profitably exploitable (Cox, Ingersoll, & Ross, 1981 ; Stoll & Whaley, 1990). When these arbitrage opportunities are exploited early by the arbitrageurs, it improves the efficiency of the price discovery process in the markets and will offer benefits to hedgers in the form of basis risk reduction (Merrick, 1988). However, in real life, law of one price is violated considerably due to many possible reasons such as non - frequent and non-synchronous trading of the asset in two markets ; market conflicts such as short sale restrictions; transaction cost difference; purpose for which the futures contract is used; and difference in returns generation between the markets.

India is an agriculture-dominated country where spot markets are highly scattered for agricultural commodities. Trading in futures protect the farmers and traders from price fluctuations and relieves them from the trouble of maintaining stocks besides making available the price information to them. The price discovery function enables setting up a base price which provides a clue to the potential spot prices. Price discovery hinges on the impact of new information in the market on the futures or spot prices. Relationship of lead-lag between futures and spot market is set on the basis of first impact of the new information on spot price or futures price. Futures markets are helpful in providing price indication for decisions relating to resource allocation. An arbitrage opportunity presents itself when resource misallocation and risk mismanagement arises, leading to distortions in the futures and spot price linkages. It is in this situation that arbitrageurs go long or short in futures contracts while simultaneously buying or selling the product. Having stated that arbitrage opportunities exist in the futures market from time to time, the error correction mechanism starts in spot market and/or futures market, which pulls the price back to the normal again in the long-run. In this backdrop, the current study seeks to investigate the presence of arbitrage, error correction mechanism, and the causality relationship in context of futures and spot market of four highly traded agricultural commodities traded on the Multi Commodity Exchange of India (MCX) namely, cardamom, cotton, crude palm oil, and mentha oil.

The rationale behind selecting these four commodities is that currently, these commodities' contracts are most active on the MCX platform. There may be many other significant commodities being traded on many national and regional exchanges, but data for these are not necessarily available from MCX. MCX is India's most significant futures exchange offering commodity futures trading across diverse segments such as bullion, metals, energy, and agricultural commodities with over 90% market share in terms of the value of commodity futures contracts traded in the financial year 2018. The market for Indian agricultural commodities has witnessed many ups and downs in the past years. It has seen reasonable growth during the recent past time due to government actions and farmers' awareness and is still a growing market. An in-depth study is required relating to the presence of arbitrage opportunities in context of agricultural commodities' spot and futures trading, which can contribute to the theory with more accuracy. This research study makes an attempt in that direction and seeks to fill this research gap. Also, this study covers a fairly long time period, that is, from 2007 to 2017, which can better provide the results with more accuracy.

Here is the brief overview of these agricultural commodities taken for the study. Cardamom is the 'queen of spices' and is an exotic and overly priced spice. India stands second in the world after Guatemala in the production, consumption, and export of this spice. Indian cardamom is smaller in size, but more aromatic. Cardamom futures were launched on MCX in 2006, and its prices are considerably volatile. Cotton fiber is an important textile fiber,

Table 1. Trading Volume and Total Value of Trading of Cardamom, Cotton, Crude Palm Oil, & Mentha Oil on MCX

	Cardamom		Cotton		Crude Palm Oil		Mentha Oil	
	Trading Volume (000's)	Total Value (Lacs)	Trading Volume (000's)	Total Value (Lacs)	Trading Volume (000's)	Total Value (Lacs)	Trading Volume (000's)	Total Value (Lacs)
2007	82890.20	415066.19	NA	NA	NA	NA	294029.64	1625774.77
2008	43954.00	290995.99	NA	NA	1345700.00	494048.19	153008.28	847611.43
2009	23389.80	182346.38	NA	NA	3761560.00	1265898.71	182175.12	1011410.54
2010	63574.90	901410.50	NA	NA	4253770.00	1773214.28	565593.48	5013965.14
2011	107401.40	936781.27	1171.50	202609.28	9333640.00	4730723.23	564810.12	6659252.09
2012	273182.70	2866931.30	10186.63	1739017.13	19348390.00	10002355.57	824090.04	12470449.09
2013	170817.60	1419637.72	24534.10	4736423.90	10691900.00	5195761.47	579530.16	6153777.16
2014	78240.30	685275.20	26933.43	5253551.49	8565680.00	4351148.42	351843.84	2680333.40
2015	44868.00	407143.33	17345.48	2747702.24	9491670.00	4048051.43	477110.16	4448358.22
2016	26469.50	242076.16	26873.88	4998455.66	11597830.00	6046474.99	257947.56	2334906.71
2017	7897.30	99580.01	21670.50	4388191.11	8380060.00	4423699.59	231885.72	2775663.87

Source : www.mcxindia.com

accounting for more than 35% of the world's total textile fiber used. Cotton's strength and capacity to be washed and dyed make it bendable to a huge variety of textile products. Cotton futures started in India as the first derivative in 1875. Today, India is on the second position regarding cotton production, consumption, and export after China. Lively derivatives in cotton are essential for Indian traders to actively do price risk management as textile is one of the largest industries in this country. Crude palm oil is the edible vegetable oil which is widely-produced in many countries. India is a big importing country regarding crude palm oil and fulfills over 30% of its yearly edible oil demand through its imports. Its futures were launched on MCX in the year 2004. Mentha oil is known by the name 'Japanese pudina' in India, and it is an aromatic herb. Mentha oil and its by-products are used in many industries such as food, pharmaceutical, flavoring, and perfumery. India is the leading producing and exporting country for mentha oil ; other leading producers being China, Brazil, and the USA.

The Table 1 shows the year-wise trading volume of these commodities in terms of their respective units and also the total value of trading in these commodities in ₹ lakhs year-wise on MCX.

Review of Literature

There are various studies, which stipulate that even though futures and spot markets observe strong and steady comovement in the long-run, there exists the relationship of lead-lag between these markets in the short-run, which may put forward profit grabbing arbitrage opportunities.

Easwaran and Ramasundaram (2008) conducted a study in context of agricultural commodities namely, cotton, pepper, castor, and soya for examining the efficiency of price discovery. The efficiency of futures markets was not found in case of all commodities under study. These markets did not perform their price discovery role and were not capable of providing a hedge against the price fluctuations due to reasons such as ignorance of farmers, irregular and infrequent trading, etc. Mahalik, Acharya, and Babu (2009) analyzed the price discovery as well as the spillover of volatility in context of MCX, India indices spot and futures markets by employing VECM and two

variable EGARCH model. The empirical results of the study showed that futures markets of MCXAgri, MCXEnergy, and MCXComdex were efficient in price discovery, indicating the information flow from futures to spot markets. The study suggested that the commodity futures market was very efficient and innovative as it incorporated all price related information, and therefore, the expected futures price of spot market could be realized by the investors. Hernandez and Torero (2010) examined the dynamic spot - futures prices interactions in context of three agricultural commodities, wheat, soybeans, and corn to find out the flow of information across these markets. Applying linear as well as non - linear Granger causality tests, the authors confirmed the futures market role in price discovery and emphasized that owing to a rise in the significance of online futures trading, there was an improvement in the flow of information from the futures market to spot markets over the earlier years, leading to transparency and accessibility of prices.

Iyer and Pillai (2010) examined the role of futures market as a hedging tool and analyzed the convergence rate of information across spot and futures markets. Using threshold vector autoregression (TVAR) and threshold autoregression, the authors tested the two-regime data in context of six commodities. The authors provided evidence that futures market was dominating in price discovery for five commodities, and convergence information rate was sluggish, particularly at the time of futures contract non - expiry week. Ali and Bardhan Gupta (2011) undertook a study to explore the spot and futures prices interactions of the agricultural commodity market in India focusing on 12 important commodities traded at NCDEX, India. The cointegration analysis proved the existence of long-term cointegration for a majority of the commodities. Using Granger causality test, the study supported short-run causality from futures to spot markets for castor seed, chickpea, sugar, and soybean, while two - way causality was found to be existing for other commodities. Thus, the study concluded that although the futures market was prominent in price discovery in India ; still, the spot market of some commodities was more active in the short-run. Baldi, Peri, and Vandone (2011) tested the cointegration and causality in spot-futures prices of soybean and corn in the U.S. after considering the structural breaks in prices of commodities. The study concluded that owing to higher transparency and liquidity, futures market of food products dominated in price discovery and swiftly responded to fresh information. Nonetheless, the cash market also becomes a chief market player during the crisis time and during the time of price rise.

Sehgal, Rajput, and Dua (2012) studied the interactions between spot and futures prices in terms of price discovery for 10 commodities of agricultural category traded at NCDEX, India. All commodities except turmeric were a having long-term cointegrating relationship. The results of Granger causality test confirmed two-way causal linkages in spot-futures prices for all commodities except turmeric. Chauhan, Singh, and Arora (2013) investigated the spillover of volatility in spot - futures markets of two agricultural commodities, guarseed and chana. Using error correction and GARCH model, the authors found evidence to confirm that two directional information flow was happening between spot and futures markets of guarseed, with stronger spillovers from futures to spot market. However, in case of chana, flow of information was happening in a single direction, with strong spillover from spot to futures market. The authors suggested that futures markets of the commodities were generally efficient than the spot markets due to more transaction volume and more liquidity. Sehgal, Rajput, and Deisting (2013) examined the dynamic process of price discovery as well as volatility spillover between futures and spot markets of 12 frequently traded commodities and four popular indices of MCX, India. Applying ECM and exogeneity test, the study confirmed price discovery in case of three indices as well as eight commodities explaining the dominant role of futures market in the price discovery process. It was stated in the study that even though the price discovery results were better, efficient risk transmission system was yet to evolve in the Indian commodity market for a majority of the commodities.

Soni and Singla (2013) also studied efficiency and unbiasedness of guar gum derivative contract with varied maturities traded at NCDEX. All these futures contracts of this commodity were not found to be efficient in both short and long term owing to speculative reasons. Babu and Srinivasan (2014) also examined the commodity

market efficiency in India using the data of spot and futures prices of 10 agricultural commodities. The study concluded that the futures prices of commodities were not impacted by their spot prices. Shakeel and Purankar (2014) tested the price discovery dynamics in context of three most actively traded agricultural commodities on NCDEX, India namely chana, soyabean, and castor seed. The results of VECM proved the two way causality relationships in all commodities' spot and futures markets, suggesting that in the price discovery process, both spot and futures markets were active and informational efficient. The study put forth that these markets had been on the way to become more informational efficient and mature because ample measures are adopted by the regulators for their growth.

Sharma (2015) studied the long-term and short-term causality using VECM and Wald's test in context of spot and futures prices of selected agricultural commodities, which were traded at NCDEX. Cointegration was established in case of four commodities : soyabean, chana, soya oil, and pepper. The results of VECM provided evidence of futures market leading the spot market in case of commodity soyabean and soya oil ; whereas, bidirectional relationship was observed for chana and pepper. Vasantha and Mallikarjunappa (2015) examined the price discovery process and lead and lag linkages between the spot and futures market for pepper traded on NCDEX, India. Using the VECM - EGARCH model, the study concluded that in case of pepper, spot market was better in efficiency than the futures market, and also, it led its futures market. The authors also stated the reasons for spot market domination as thin trading volume in futures market, futures market limited awareness in participants, and active spot markets in Kerala and Karnataka where pepper was cultivated.

Vimal (2015) studied the Indian agricultural commodity markets for their efficiency using the data of seven agri commodities traded on NCDEX. The results proved that in spite of the long term relationship between spot and futures prices of all commodities, the causal relations were different for different commodities. There existed unidirectional causal relation in case of three commodities and bidirectional relationship in case of four commodities, with the futures market having a lead in price discovery, hence proving its efficiency in India. Irfan and Hooda (2017) conducted a study on 10 agricultural commodities from NCDEX with the objective to find out the effectiveness of futures market in their price discovery. The study highlighted that the futures and spot prices of all commodities were cointegrated as well as there was a single direction Granger causal relationship between the prices. Narsimhulu and Satyanarayana (2016) also stipulated in their study that futures markets of commodities in India were effective in risk management and hedging. The authors conducted a study on three agricultural commodities from NCDEX, and the causality results revealed that there was a single directional causal impact from futures to spot market in case of chilli and turmeric and bidirectional causal relation in case of the commodity : chana. Gupta, Choudhary, and Agarwal (2018) studied the price discovery along with market efficiency in the long - term in context of eight commodities, including two agri commodities. Using the methods of restricted cointegration and VECM, the study found that futures prices of all the commodities were not helpful in the prediction of their spot prices. They put forth that the commodity market in India was in its nascent stage and was also a thinly traded market. Specifically, the results of VECM showed that the Indian commodity market was informational inefficient, contributing to biased prices in the short run.

Empirical works have found evidences of substantial mispricing between futures and spot markets, which results in the deviation between these prices. An arbitrageur trades primarily in futures nearest to delivery. The risk related to arbitrage trading is observed to be little so that the profits are almost risk free (Bühler & Kempf, 1995). A possible explanation for the potential determinant of mispricing may be irregular and asynchronous asset trading between the markets (Neal, 1996). Pricing errors are present resulting into profitable, though small arbitrage opportunities. The authors found that besides the model misspecification, pricing errors may be positively linked to time-to-maturity and non-convertibility in the market (Brailsford & Cusack, 1997).

The review of literature brings to light that even though the futures and spot markets may be in equilibrium in the long-run, but there may arise significant profitable and exploitable arbitrage opportunities in the short-run,

leading the markets to do the correction of the mispricing. This error correction in the markets sets up the relation of lead-lag between the markets, thereby bringing them into equilibrium again. The current study seeks to address this issue empirically to examine the arbitrage, error correction, and causality in respect of highly traded agricultural commodities on MCX, India.

Objectives and Methodology

(1) Objective : The aim of the study is to examine the speed, magnitude, and significance of error correction in the presence of arbitrage opportunities and also examine the causality relation between the futures and spot prices of selected highly traded agricultural commodities in context of the Indian commodity market. The following are the two hypotheses which need to be tested :

↳ **H1 :** There exists significant error correction mechanism between the futures and spot prices of selected agricultural commodities in the Indian commodity market.

↳ **H2 :** There exists significant causality between the futures and spot prices of selected agricultural commodities in the Indian commodity market.

(2) Data : The study uses a sample of four most actively traded agricultural commodities on the Multi Commodity Exchange of India Ltd. (MCX), that is, cardamom, cotton, crude palm oil, and mentha oil. The study is based on daily data consisting of futures and spot closing prices of these commodities. The period of the study is from 2007 to 2017 for the commodities : cardamom and mentha oil. For crude palm oil, the data period is from 2008 to 2017 ; and for cotton, the data period is 2011 to 2017. The difference of data period of these commodities is due to their late trading launch on the exchange. The data were collected from the website of MCX, that is, www.mcxindia.com.

(3) Methodology : In the first step, the descriptive statistics of the time series data have been examined, which summarize a given data set in terms of measures of central tendency, measures of variability, kurtosis, and skewness. Augmented Dickey - Fuller (ADF) unit root test and Phillips and Perron (PP) test are applied on the individual price series to examine the stationarity or non - stationarity of the data. Since the selected agricultural commodity futures and spot prices are found to have the same order of integration, Johansen's co-integration test is used to study the long-run relationship between the price pairs. Once the results of the co-integration confirm that the variables are cointegrated in the long-term, the vector error correction model (VECM) is used to determine the error correction process in the short-term between the spot and futures markets of selected highly traded agricultural commodities. The ECM helps to identify the market, which plays an influential role in explaining the efficiency of information in the process of price discovery. The error correction model can be mathematically expressed as:

$$\Delta F_t = \delta_f + \alpha_f \hat{e_{t-1}} + \beta_f \Delta F_{t-1} + Y_f \Delta S_{t-1} + \varepsilon_{ft} \quad (1)$$

$$\Delta S_t = \delta_s + \alpha_s \hat{e_{t-1}} + \beta_f \Delta S_{t-1} + Y_f \Delta F_{t-1} + \varepsilon_{st} \quad (2)$$

In these equations, F_t and S_t are futures and spot commodity prices at time t. The term $\hat{e_{t-1}}$ denotes the disequilibrium error measuring the adjustment done by the dependent variable towards deviation of the previous period arising from the long - run equilibrium. The rest of the equation explains the lagged first

difference of the variable representing the previous period's price change effect on the short-run in the present period's deviation. The equilibrium error coefficients, α_f and α_s are very significant in ECM as these actually measure the adjustment speed of the variable or convergence to reach the long - run stable relation again.

In the next step, VEC Granger causality/block exogeneity Wald test and impulse response function are applied to examine the causality relations between futures and spot commodity markets. The block exogeneity test suggests whether the variable in the system has a significant impact on the future values of other variables used in the model. Rather than examining the individual coefficient estimates, combined significance of a particular variable's lagged coefficients in the equation can be studied to determine causality in the ECM. This kind of significance testing can be performed with the standard chi - square test or Wald-test used for assessment of parameter restrictions and is known as the VEC Granger causality/block exogeneity Wald test. However, sign of relation and longevity of the effects in the system cannot be worked out through this test. As such, the impulse response function is employed to capture the impact of a shock in a particular variable at a given time point on the predicted values of other variables in the system. Impulse response function (IRF) outlines the endogenous variable's response to the unit shock to each of the variables in the system.

Analysis and Results

The analysis starts with the descriptive statistics of the futures and spot price series of all the four highly traded agricultural commodities. The results of descriptive statistics are reported in the Table 2.

The descriptive statistics of these agricultural commodities under study show that the mean, median, maximum, and minimum values of futures and spot price series of all the commodities are almost similar. High standard deviation values indicate that the data is highly dispersed. Skewness values indicate that the data for all the commodities under study is far from zero, suggestive of asymmetric distribution. The data is either positively skewed or negatively skewed. The kurtosis values of commodities indicate that the distribution is leptokurtic and far from normal distribution. The values of Jarque - Bera are significant at the 1% level, indicating that the null hypothesis of normal distribution stands rejected. Thus, the results confirm asymmetric, highly volatile, and non - normal distribution of the futures and spot price series of all the commodities under study.

In the next step, the time graphs of all the commodities' futures and spot prices are exhibited to have an idea about the trend and movements in the price series over time. The graphs present a glimpse of the data with the fact that the price series are co-moving and are highly volatile. This serves as a base to test the co-movements in the price series both in the long-run as well as in the short-run for these commodities. The graphs of the futures and spot price series of the selected commodities are exhibited in the Figure 1.

Table 2. Descriptive Statistics of Commodities

Price Series	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera
CARDAM (F)	882.11	815.40	2038.20	367.00	291.12	0.92	3.59	458.14**
CARDAM (S)	865.00	805.13	1770.00	373.50	287.83	0.80	3.22	321.85**
COTTON (F)	18077.96	17830.00	23650.00	13990.00	1988.75	0.34	2.02	90.45**
COTTON (S)	18140.28	17880.00	23720.00	14420.00	2154.70	0.45	2.17	96.56**
CPALMOIL (F)	462.15	475.90	628.70	232.30	86.96	-0.48	2.35	140.25**
CPALMOIL (S)	462.31	475.90	622.30	48.00	88.06	-0.49	2.45	133.24**
MENOIL (F)	867.51	850.20	2570.30	416.20	335.64	1.31	6.11	2033.71**
MENOIL (S)	955.98	958.75	2769.30	477.10	375.96	1.12	5.29	1264.78**

Note. ** indicates significance at 1% level.

Figure 1. Graphs Showing Trends and Movements in the Data

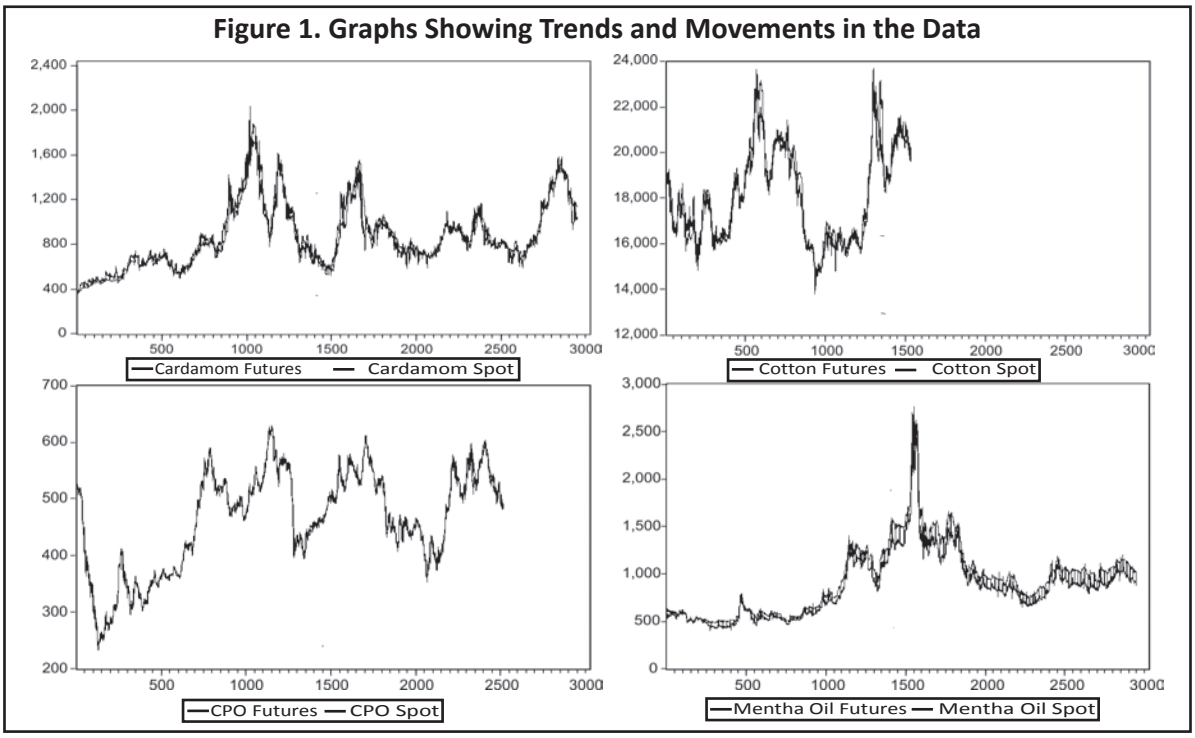


Table 3. Results of Stationarity Tests for Agricultural Commodities

	ADF Test		PP Test	
Price Series	**Levels**	**Ist Difference**	**Levels**	**Ist Difference**
CARDAM (F)	-3.228	-55.170	-2.950	-55.659
CARDAM (S)	-2.415	-22.112	-2.519	-49.441
COTTON (F)	-2.193	-41.193	-2.114	-41.202
COTTON (S)	-1.706	-30.179	-2.153	-32.598
CPALMOIL (F)	-2.503	-31.329	-2.720	-48.477
CPALMOIL (S)	-2.532	-48.116	-2.921	-77.194
MENOIL (F)	-2.135	-48.527	-2.530	-74.342
MENOIL (S)	-2.333	-12.746	-2.044	-43.152

The Augmented Dickey - Fuller (ADF) unit test is employed for stationarity testing of the price pairs of futures and spot series of the commodities and the results are presented in the Table 3. The results of price series confirm their non - stationarity, which is also a compulsory circumstance so as to apply Johansen's cointegration test. The results of return series of these commodities exhibit stationarity, confirming that both spot and futures commodity prices are integrated to the first order. To add value to the results, Phillips and Perron (PP) test has also been performed on the data. The results of PP test validate and cross check the results of ADF test, that is, the data are non-stationary at levels and stationary at first difference.

Same order of integration of spot and futures price series provides a base to apply the cointegration technique to know about the long-run steady relation between the series. Johansen's cointegration analysis exposes the co-movements of the two markets towards the long-run equilibrium.

Table 4. Results of Johansen's Cointegration Test

Commodity	Hypothesized No. of CE(s)	Eigenvalue	Trace Test			Maximum Eigenvalue Test		
			Trace Statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
Cardamom	None*	0.042	131.197	12.321	0.000	131.056	11.225	0.000
	At most 1	0.000	0.141	4.130	0.757	0.141	4.130	0.757
Cotton	None*	0.024	40.878	12.321	0.000	0.024	11.225	0.000
	At most 1	0.000	0.013	4.130	0.925	0.000	4.130	0.925
Crude Palm Oil	None*	0.046	124.996	12.321	0.000	124.936	11.225	0.000
	At most 1	0.000	0.060	4.130	0.840	0.060	4.130	0.840
Mentha Oil	None*	0.0371	116.485	12.321	0.000	116.039	11.225	0.000
	At most 1	0.000	0.445	4.130	0.568	0.445	4.130	0.568

Note. Trace test indicates 1 cointegrating eqn(s) at the 0.05 level.

Max - Eigen value test indicates 1 cointegrating eqn(s) at the 0.05 level.

* denotes rejection of the hypothesis at the 0.05 level.

** MacKinnon - Haag - Michelis (1999) *p* - values.

The results of Johansen's trace test and maximum Eigen value test as shown in the Table 4 indicate the existence of one cointegrating equation between the price pairs at 5% significance level in case of all the four agricultural commodities under study. These results confirm the futures-spot price pairs of these agricultural commodities to have a stable long-run relationship and strong co-movements resulting in convergence of prices on the date of maturity. This proves that futures and spot price series of all the selected commodities are maintaining an equilibrium relationship in the long-term. The cointegration results also suggest that the price discovery takes place in the futures and spot commodity markets. These results are consistent with the results of previous studies such as Mahalik et al. (2009), Sehgal et al. (2012), Palamalai (2012), Sehgal et al. (2013), Vasantha and Mallikarjunappa (2015), and Shanmugam and Raghu (2016).

To proceed further in the analysis of data, the vector error correction model (VECM) has been applied to ascertain the magnitude, speed, and significance of error correction done by futures and spot prices in the short-run. The error correction term (ECTs) coefficients give knowledge of the adjustment process happening in futures and/or spot prices in the process of reaching equilibrium in the short-run. Before employing VECM, it is important to find out the optimum lag length. Lag length for all the commodities has been selected using VAR lag order selection criteria using Hannan - Quinn information criterion (HQ), and all calculations have been done using that lag length. The results of VECM are reported in the Table 5.

The results of VECM, as shown in Table 5, indicate the coefficients of cointegrating equation along with the

Table 5. Results of Vector Error Correction Model (VECM)

Commodity	DV : Futures Series			DV : Spot Series		
	Coefficient	Std. error	*t*-statistics	Coefficient	Std. error	*t*-statistics
Cardamom	-0.044	0.009	-4.772	0.036	0.004	7.982
Cotton	-0.0132	0.012	-1.111	0.038	0.007	5.620
Crude Palm Oil	-0.069	0.024	-2.945	0.081	0.019	4.217
Mentha Oil	0.149	0.017	8.901	-0.002	0.010	-0.293

Note. * Significant at 5% level.

standard error and *t* - statistic for the futures and spot markets of the selected commodities namely, cardamom, cotton, crude palm oil, and mentha oil. Here, the coefficient is a measure of speed of adjustment during the process of error correction mechanism lying between futures and spot markets of the commodity. The speed of adjustment is found to be higher from spot to futures market in case of two commodities, cardamom and mentha oil ; whereas, the speed of adjustment is higher from futures to spot market in case of the other two commodities, that is, cotton and crude palm oil. The significance of the speed of adjustment is analyzed with the help of *t* - statistics. Here, the *t*-statistics test the null hypothesis that the speed of adjustment from the respective market is zero. The results indicate that the speed of adjustment is found to be highly significant from futures to spot market to the error or disturbance in the long-run relationship between futures and spot market. In addition to this, the results indicate that the *t*-statistics of the spot to futures market is also found to be significant. Thus, it can be concluded from the results that both the markets are responding to the disturbance in the relationship, where the speed of adjustment is higher in case of the futures market. However, speed of adjustment is found to be more significant in case of the spot market. The results support that in case of disequilibrium in the theoretical cost-of-carry relationship in the markets in the short-term, arbitrage opportunities arise and arbitrageurs take positions in different markets to take benefit of mispricing. These actions of the market participants lead to error correction and evaporation of arbitrage opportunities, thereby helping the markets to be in equilibrium again. The results also point out that the futures market plays a dominant role in the price discovery process generally and contains important information for the potential changes in spot prices in the short-run.

Hence, we fail to reject the first hypothesis (H1) which states that there exists a significant error correction mechanism between the futures and spot prices of selected agricultural commodities in the Indian commodity market.

The second part of the analysis involves testing whether the causality relationship exists between the futures and spot prices of the selected commodities. For this purpose, Block exogeneity Wald test is applied to examine the impact of each variable on the other. The results of the test are shown in the Table 6(a) and Table 6(b).

The results of Table 6(a) and Table 6(b) indicate a bi-directional causality between futures and spot markets of selected agricultural commodities under study. The results clarify that spot price of any commodity is causing its futures price as well as the futures price is also causing its spot price. The magnitude of chi - square is found to be high in case of causality in the direction of futures to spot market. Only in case of mentha oil, magnitude of

Table 6(a). VEC Granger Causality/Block Exogeneity Wald Test Dependent Variable : Futures Prices

Cardamom		Cotton		Crude Palm Oil		Mentha Oil	
Excluded	**Chi-Square (Prob.)**	**Excluded**	**Chi-Square (Prob.)**	**Excluded**	**Chi-Square (Prob.)**	**Excluded**	**Chi-Square (Prob.)**
Cardamom	68.7434*	Cotton	9.453*	Crude Palm Oil	68.0248*	Mentha Oil	168.026*
Spot	(0.0000)	Spot	(0.041)	Spot	(0.0000)	Spot	(0.0000)

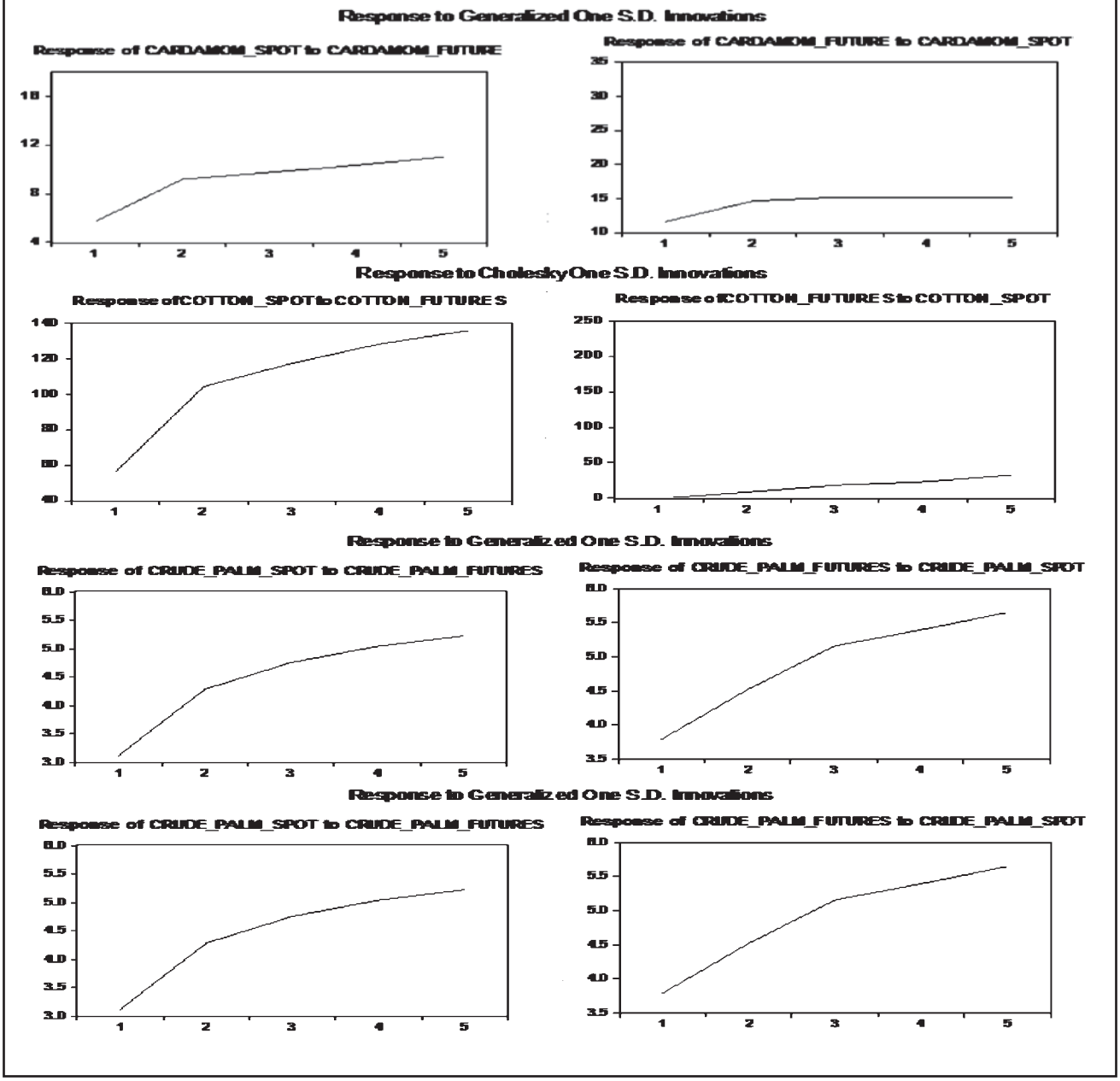
Note. * indicates significance at 5%.

Table 6(b). VEC Granger Causality/Block Exogeneity Wald Test Dependent Variable : Spot Prices

Cardamom		Cotton		Crude Palm Oil		Mentha Oil	
Excluded	**Chi-Square (Prob.)**	**Excluded**	**Chi-Square (Prob.)**	**Excluded**	**Chi-Square (Prob.)**	**Excluded**	**Chi-Square (Prob.)**
Cardamom	71.7521*	Cotton	101.082*	Crude Palm Oil	89.7582*	Mentha Oil	46.811*
Futures	(0.0000)	Futures	(0.000)	Futures	(0.0000)	Futures	(0.0000)

Note. * indicates significance at 5%.

Figure 2. Results of Impulse Response Function (IRF)



chi - square is very high in the direction from spot market to futures market. These results are indicative of the fact that there exists bi-directional causality between the futures and spot markets of agricultural commodities, but in general, the futures markets strongly Granger cause spot markets than the other way round. These results corroborate with the earlier results obtained from VECM.

The impulse response function (IRF) in time - series analysis is helpful in studying the response of one series to the unexpected shocks in the other series. The IRF of different pairs of futures and spot markets of all the four commodities is shown in the Figure 2.

The IRF plots of all the commodities, as shown in Figure 2, indicate that the response of spot market to the sudden shock in the futures market is high in case of three commodities, namely cardamom, cotton, and crude

palm oil. In case of mentha oil, response of the futures market to the unexpected shock of the spot market is high. Thus, the futures market is more dynamic and significantly causes the spot market in case of majority of the commodities under study. The results of the test indicate that the futures market is highly exogenous in nature as compared to the spot market. This also means that the futures prices are more influenced by external factors ; whereas, the spot prices are influenced more by futures prices as compared to external factors. Thus, we fail to reject the second hypothesis (H2) which states that there exists significant causality between the futures and spot prices of selected agricultural commodities in the Indian commodity market.

Summary and Conclusion

The present study confirms the existence of arbitrage and error correction in short-run in futures and spot markets of highly traded agricultural commodities in India. The study concludes that in the long-run, futures and spot prices of all the four highly traded agricultural commodities, namely, cardamom, cotton, crude palm oil, and mentha oil are co-integrated, which suggests the efficiency of arbitrage mechanism in the agricultural commodity markets in India in the long-run. Existence of cointegration between futures and spot markets is also indicative of both markets sharing a common set of information, therefore, law of one price holds good in the long-run. However, in the short-run, there arises disequilibrium, resulting in exploitable arbitrage opportunities. Trading by the arbitrageurs in these markets leads to significant error correction, thereby bringing the markets into equilibrium again. The results of the study can be summarized as follows :

Commodities	Speed of Error Correction	Significance of Error Correction	Causality
Cardamom	S → F	Spot & Futures markets	Bi-directional
Cotton	F → S	Spot market	Bi-directional
Crude Palm Oil	F → S	Spot & Futures markets	Bi-directional
Mentha Oil	S → F	Futures market	Bi-directional

The results confirm that both futures and spot markets are responding to the disturbance in the relationship, where the speed of adjustment is higher in case of the futures market. However, speed of adjustment is found to be more significant in case of the spot market. Also, bi-directional causality between the futures and spot markets is observed in case of all the commodities, but in general, the futures market Granger causes the spot market strongly than the other way round. Thus, the study fails to reject both the hypotheses as there exists significant error correction as well as causality between the futures and spot prices of selected agricultural commodities in the Indian commodity markets.

Overall, the results also prove that arbitrage opportunities are present in futures and spot trading of agricultural commodities in India in the short run. These opportunities are profitably grabbed by the investors and arbitrageurs present in the market due to which error correction takes place and the two prices again reach the equilibrium in the long-run. Also, the futures market is acting dominantly in the price discovery mechanism and contains important information for the potential changes in spot prices in short-run. Theoretically, it is believed that the futures market leads the spot market in the price discovery process mainly due to the functional superiorities of the futures market in terms of high liquidity, low transaction costs, low margins, easy leverage positions, and more flexibility in contract execution. As such, farmers/traders are more attracted towards dealing in the futures market, and this makes the futures market to react first on the arrival of new information. These findings are in accordance with the results obtained by previous studies such as Zapata, Randall, and Armstrong (2005) ; Bose (2007) ; Mahalik et al. (2009) ; Hernandez and Torero (2010) ; Ali and Bardhan Gupta (2011) ; Baldi et al. (2011) ; and Sendhil, Kar, Mathur, and Jha (2013).

Implications, Limitations of the Study, and the Way Forward

The knowledge of presence of arbitrage opportunities in spot or futures commodity markets enable the traders to gain profits by acting quickly in these markets as these opportunities arise for a very short time period only. The information about the error correction and long-run market equilibrium relationship is vital for farmers, traders, and organizations occupied in production, trading, processing, and marketing of these commodities. The study throws light on the possibility of acting of spot or futures prices as an efficient price discovery vehicle, and this will be massively valuable for farmers and traders to hedge their market risk. Also, the findings will be constructive for the regulators to devise and execute policy and control measures to increase the efficiency of the system to ensure stability of the Indian commodity markets.

Even though the study is innovative and distinctive, yet it has few limitations such as confinement to agricultural commodities only ; use of data from only one exchange, that is, MCX ; not considering high-frequency minute-by-minute data, etc. However, the study offers ample scope of carrying out research in related areas. Arbitrage and error correction mechanism can be tested for non-agricultural highly traded commodities of MCX. Data from NCDEX or other commodity exchanges can also be used for a comparative study. The study may also be conducted by using high frequency data. The results of arbitrage and error correction mechanism of agricultural commodities of India may be compared with their international counterparts.

References

Ali, J., & Bardhan Gupta, K. (2011). Efficiency in agricultural commodity futures markets in India: Evidence from cointegration and causality tests. *Agricultural Finance Review, 71*(2), 162 - 178. DOI : 10.1108/00021461111152555

Babu, M., & Srinivasan, S. (2014). Testing the co-integration in Indian commodity markets : A study with reference to Multi Commodity Exchange India Ltd. *Indian Journal of Finance, 8*(3), 35 - 43. DOI : 10.17010/ijf/2014/v8i3/71961

Baldi, L., Peri, M., & Vandone, D. (2011). *Price discovery in agricultural commodities: The shifting relationship between spot and futures prices.* In EAAE 2011 Congress, Change and Uncertainty Challenges for Agriculture, Food and Natural Resources, August 30 - September 2, 2011, Zurich, Switzerland.

Bose, S. (2007). Contribution of Indian index futures to price formation in the stock market. *Money and Finance, 3*(1), 39 - 56.

Brailsford, T. J., & Cusack, A. J. (1997). A comparison of futures pricing models in a new market: The case of individual share futures. *Journal of Futures Markets: Futures, Options, and Other Derivative Products, 17*(5), 515 - 541.

Bühler, W., & Kempf, A. (1995). DAX index futures: Mispricing and arbitrage in German markets. *Journal of Futures Markets, 15*(7), 833 - 859.

Chauhan, A. K., Singh, S., & Arora, A. (2013). Market efficiency and volatility spillovers in futures and spot commodity market: The agricultural sector perspective. *Samvad, 6*(2), 61 - 84.

Cox, J. C., Ingersoll, J. E., & Ross, S. A. (1981). The relation between forward prices and futures prices. *Journal of Financial Economics, 9*(4) 321 - 346.

Easwaran, R. S., & Ramasundaram, P. (2008). Whether commodity futures market in agriculture is efficient in price discovery ? - An econometric analysis. *Agricultural Economics Research Review, 21,* 337 - 344.

Gupta, S., Choudhary, H., & Agarwal, D. R. (2018). An empirical analysis of market efficiency and price discovery in Indian commodity market. *Global Business Review, 19*(3), 771 - 789. DOI : 10.1177/0972150917713882

Hernandez, M., & Torero, M. (2010). *Examining the dynamic relationship between spot and futures prices of agricultural commodities* (IFPRI Discusssion Paper No. 00988). Retrieved from http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/2258/filename/2259.pdf

Irfan, M., & Hooda, J. (2017). An empirical study of price discovery in commodities futures market. *Indian Journal of Finance, 11*(3), 41 - 57. DOI : 10.17010/ijf/2017/v11i3/111648

Iyer, V., & Pillai, A. (2010). Price discovery and convergence in the Indian commodities market. *Indian Growth and Development Review, 3*(1), 53 - 61. DOI : 10.1108/17538251011035873

Mahalik, M. K., Acharya, D., & Babu, M. S. (2009). *Price discovery and volatility spillovers in futures and spot commodity markets: Some empirical evidence from India* (IGIDR Proceedings/Project Reports Series PP - 062-10). Retrieved from http://www.igidr.ac.in/pdf/publication/PP-062-10.pdf

Merrick, J. J. (1988). Hedging with mispriced futures. *Journal of Financial and Quantitative Analysis, 23*(4), 451 - 464. DOI : 10.2307/2331083

Narsimhulu, S., & Satyanarayana, S. V. (2016). Efficiency of commodity futures in price discovery and risk management : An empirical study of agricultural commodities in India. *Indian Journal of Finance, 10* (10), 7 - 26. DOI : 10.17010/ijf/2016/v10i10/102990

Neal, R. (1996). Direct tests of index arbitrage models. *Journal of Financial and Quantitative Analysis, 31*(4), 541 - 562. DOI : 10.2307/2331359

Palamalai, S. (2012). *Price discovery and volatility spillovers in Indian spot-futures commodity market.* Retrieved from https://ssrn.com/abstract=2152867

Sehgal, S., Rajput, N., & Dua, R. K. (2012). Price discovery in Indian agricultural commodity markets. *International Journal of Accounting and Financial Reporting, 2*(2), 34 - 54. DOI : 10.5296/ijafr.v2i2.2224

Sehgal, S., Rajput, N., & Deisting, F. (2013). Price discovery and volatility spillover : Evidence from Indian commodity markets. *The International Journal of Business and Finance Research, 7*(3), 57 - 75.

Sendhil, R., Kar, A., Mathur, V. C., & Jha, G. K. (2013). Price discovery, transmission and volatility: Evidence from agricultural commodity futures. *Agricultural Economics Research Review, 26*(1), 41 - 54.

Shakeel, M., & Purankar, S. (2014). Price discovery mechanism of spot and futures market in India : A case of selected agri-commodities. *International Research Journal of Business and Management, 8*(8), 50 - 61.

Shanmugam, V. P., & Raghu, R. R. (2016). *Relationship between spot and futures markets of selected agricultural commodities: An efficiency and causation analysis.* Retrieved from https://ssrn.com/abstract=2995347

Sharma, T. (2015). An empirical analysis of commodity future market in India. *International Journal of Engineering Technology, Management and Applied Sciences, 3*, 11 - 19.

Soni, T. K., & Singla, H. K. (2013). A study of the efficiency and unbiasedness in NCDEX : A case study of Guar Gum. *Indian Journal of Finance, 7*(11), 28 - 37.

Stoll, H. R., & Whaley, R. E. (1990). The dynamics of stock index and stock index futures returns. *The Journal of Financial and Quantitative Analysis, 25*(4), 441 - 468. DOI :10.2307/2331010

Vasantha, G., & Mallikarjunappa, T. (2015). Lead-lag relationship and price discovery in Indian commodity derivatives and spot market: An example of pepper. *The IUP Journal of Applied Finance, 21*(1), 71 - 83.

Vimal, S. (2015). Testing efficiency in agricultural commodity futures market in India using cointegration and causality tests. *Indian Journal of Finance, 9*(12), 51 - 60. DOI : 10.17010/ijf/2015/v9i12/84384

Zapata, H. O., Randall, F. T., & Armstrong, D. (2005). *Price discovery in the world sugar futures and cash markets: Implications for the Domincan Republic* (Staff Paper Series No. 469). Retrieved from https://ageconsearch.umn.edu/record/12657

About the Authors

Dr. Ruchika Kaura is working as an Assistant Professor in the Department of Commerce, Atma Ram Sanatan Dharma College, University of Delhi. She has done her Ph.D. from IGNOU. Her interest areas include finance and derivative markets. She has a number of research papers to her credit.

Prof. Nawal Kishor is Professor and Former Director, School of Management Studies, IGNOU, India. His areas of specialization include international business management, international business environment, international marketing, foreign trade, export - import procedures and documentation, consumer behaviour, retail management, etc. He has more than 25 years of teaching experience at IGNOU. He has many publications in national and international journals to his credit.

Dr. Namita Rajput is presently working as Principal (OSD), Sri Aurobindo College (Evening), University of Delhi. She has more than 25 years of rich expertise in teaching, lecturing, and research & development with specialization in finance, international business, marketing, and other subjects in commerce. Being a part of various seminars, paper presentations, and business reviews, she has also authored several books and papers in national and international journals.