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PRICE DISCOVERY AND VOLATILITY SPILLOVER EFFECT IN INDIAN AGRICULTURE COMMODITY MARKET

B. Brahmaiah[1] and Srinivasan Palamalai[2]

Abstract: *This study examines the price discovery and volatility spillovers between futures and spot prices of twenty-five agricultural commodities viz., Barley, Castor Seeds, Channa, Chilli, Corriander, Cotton Seed Oil Cake, Cotton, Crude Palm Oil, Gaur Gum, Gaur Seed, Gaur, Jeera, Kapas, Maize, Menta Oil, Mustard Oil, Peas, Pepper, Potato, Rubber, Soya Bean, Soya Oil, Sugar, Turmeric and Wheat, traded on National Commodity and Derivatives Exchange (NCDEX). The study uses the daily data from 15th January 2004 to 31st March 2015. The empirical results confirm the price discovery between futures and spot prices, indicating strong information transmission from futures markets to spot markets in the case of majority of Agriculture commodities. This is followed by the feedback relationship between futures and spot market prices and one-way causal linkage from spot to futures market prices. Besides, the study results suggest that the volatility spillover effects are found to be quite strong in agri-futures market. The present study concludes that India's agriculture commodity derivatives market is evolving in the right direction as futures market has started playing crucial role in the information transmission process.*

JEL Codes: *C32, G13, G14, G15, G18.*

Keywords: *Price discovery, Volatility Spillover, Agriculture Commodity, VECM, Bivariate EGARCH.*

1. INTRODUCTION

Persistence of agricultural price instability along with farmer's direct exposure to such fluctuations remains major concerns for policy makers in India. The dimension of the problem warrants additional attention in case of agricultural products since unlike others, these carry added risk of witnessing seasonal fluctuations and attracting lower prices during harvest season. Varying economic environment, changing demand and

[1] Professor of Finance and Accounting, ICFAI Business School, Hyderabad, Telangana, India. *Email: brahmaiahb@ibsindia.org*

[2] Assistant Professor, Xavier Institute of Management and Entrepreneurship (XIME). Electronics City, Phase II, Hosur Road, Bangalore 560 100, Karnataka, India. *E-mail: srinivasaneco@gmail.com*

supply position of agricultural commodities and growing international competitions require wider roles for futures markets in an agricultural economy like India.

India is considered as a major centre for trading of agricultural commodities derivatives. Futures markets are considered as an efficient risk minimizing tool and perform several economic functions. They include hedging, price discovery, financing, liquidity and price stabilization. The existence of price discovery and volatility spillover associated with spot and futures market has been important since the genesis of futures market. Price discovery is the process by which market attempts to reach equilibrium price. In a static sense price discovery implies the existence of equilibrium price. In a dynamic sense, the price discovery process describes how information is produced and transmitted across the market. Price discovery is a major function of commodity futures market. Information on price discovery is essential since these markets are widely used by firms engaged in the production, marketing and processing of commodities. It is generally argued that price discovery in commodity futures market is more efficient than that in spot market.

The issue of price discovery and the volatility spillover is of great interest to traders, financial economists and analysts. Although futures and spot markets react to same information, the major question is which market reacts first and from which market volatility spills over to other markets. The process of price discovery facilitates the inter-temporal inventory allocation function by which market participants are able to compare the current and futures prices and decide the optimal allocation of their stocks between immediate sale and storage for futures sale. Unlike the physical market a futures market facilitates offsetting the traders without exchanging physical goods until the expiry of a contract. As a result, futures market attracts hedgers for risk management and encourages considerable external competition from those who possess market information and price judgment to trade as traders in these commodities. While hedgers have long-term perspective of the market, the traders or arbitragers prefer an immediate view of the market.

Moreover, understanding information flow across markets is important for hedge funds, portfolio managers and hedgers for hedging and devising cross-market investment strategies. Further, Kavussanos and Visvikis (2004) stated that market agents can use the volatility transmitting market in order to cover the risk exposure they challenge. Specifically, the investigation of price discovery and volatility spillover will throw light on the possibility of acting spot or future prices as an efficient price discovery vehicle, and this will be immensely useful for the traders to hedge their market risk. Besides, it provides useful insights to the arbitrageurs, who are formulating their trading strategies based on market imperfections. Further, the subject is immensely helpful for the investors and portfolio managers to develop effective trading and hedging strategies in the Indian agriculture commodity futures market.

Keeping in view the above, the present study examines the price discovery in Indian Agriculture commodity futures and spot market and to investigate whether the volatility spills over from futures to spot market or vice versa. The remainder of the article is organised as follows: Section 2 provides the review of literature. Section 3 describes the methodology and data used for empirical analysis. Section 4 offers empirical results and discussion of the study. Conclusions are presented in section 5.

2. REVIEW OF LITERATURE

Previous study by Hamao *et al.*(1990) found volatility spillover exists from the United States and United Kingdom stock markets to the Japanese stock markets. Susmel and Engle (1994) examined the spillover effect for London and New York stock exchanges and suggested that there is no evidence of spillover effect. Theodossiou and Lee (1993) observed statistically significant mean and volatility spillovers between some of the markets in the United States, United Kingdom, Canada, Germany and Japan. Koutmos and Booth (1995) found linkages between the developed markets and concluded that the volatility transmission process was asymmetric. Booth *et al.*(1997) examined the price and volatility spillovers in Scandinavian stock markets, *viz.* Danish, Norwegian, Swedish, and Finnish stock markets by employing the EGARCH model. They found that volatility transmission was asymmetric, significant price and volatility spillovers exist among some of the markets. Moosa (2002) examined the price discovery function and risk transfer in crude oil market by using Garbade and Silber (1983) model. The study uses the daily data of spot and one-month future prices of WTI crude oil covering from 2 January 1985 to July 1996. He found that price discovery function was performed in futures market. Kumar and Sunil (2004) investigated the price discovery in six Indian commodity exchanges for five commodities. They found that inability of futures market to fully incorporate information and confirmed inefficiency of futures market.

Zhong *et al.*(2004) investigated whether Mexican stock index futures markets effectively served the price discovery function, and that the introduction of futures trading led to volatility in the underlying spot market. By using VECM and EGARCH models, the empirical evidence showed that the futures price index acts as a useful price discovery vehicle and futures trading had also been a source of instability for the spot market. Zapata *et al.*(2005) examined the relationship between eleven futures contract prices traded in New York and the World cash prices for exported sugar. They found that the futures market for sugar leads the cash market in price discovery mechanism. Fu and Qing (2006) examined the price discovery process and volatility spillovers in Chinese spot-futures markets through Johansen cointegration, VECM and EGARCH model. The empirical results indicate significant bidirectional information flows between spot and futures markets in China, with futures being dominant. Besides, the volatility spillovers from futures to spot were more significant than the other way round. Praveen and Sudhakar (2006) analysed price discovery process in stock market and the commodity futures market, respectively. They have taken Nifty futures traded on National Stock Exchange (NSE) and gold futures on Multi Commodity of India (MCX). The result showed that the Nifty futures had no influence on the spot Nifty. Besides, the analysis of commodity market showed that gold futures price influenced the spot gold price, but not the other way round. Srinivasan (2009) examined the price discovery mechanism in the Nifty spot and futures market of India. The results reveal that there exists a long-run relationship between Nifty spot and Nifty futures prices.

Further, the results confirm the presence of a bidirectional relationship between the Nifty spot and Nifty futures market prices in India. It can, therefore, be concluded that both the spot and futures markets play the leading role through price discovery process in India and said to be informationally efficient and react more quickly to each other. Iyer and Pillai *(2010) had* examined whether futures markets play a dominant role in the price discovery process. They found that commodity futures market prices play the vital role in the price discovery process. Besides, Shihabudheen and Padhi (2010) examined the price discovery mechanism and volatility spillovers effect for six Indian commodity markets, *viz.*, Gold, Silver, Crude oil, Castor seed, Jeera and Sugar. The study result supported that futures price acts as an efficient price discovery vehicle except in the case of sugar. In case of sugar, the volatility spillover exists from spot to futures. Moreover, Pavabutr and Chaihetphon (2010) examined the price discovery process of the nascent gold futures contracts in the Multi Commodity Exchange of India (MCX) though vector error correction model. They found that futures prices of both standard and mini contracts lead spot price. Recently, Kumar and Shollapur (2015) analyzed the price behavior in terms of returns as well as volatility between the spot and futures markets for four commodities, *viz.* soya oil, soya bean, mustard seed and channa. They found existence of long-term equilibrium relationship between the futures and spot prices, with the futures leading the spot prices. In the short run, futures returns seem to have a stronger impact on the spot returns in most of the commodities.

It can seen be from the existing literatures on price discovery and volatility spillover that even though spot and futures markets react to the same information, the major question is which market reacts first. Considerable volume of research has been conducted on the subject, but still there exist conflicting evidences in the literature regarding the price discovery mechanism and volatility spillover effects. Besides, only a few notable studies have made an attempt on Indian commodity market with reference to individual agriculture commodity futures contract. This paper seeks to contribute to the literature on price discovery and volatility spillovers by focusing on the selected twenty-five individual agriculture commodity futures market in India, *viz.* Barley, Castor Seeds, Channa, Chilli, Corriander, Cotton Seed Oil Cake, Cotton, Crude Palm Oil, Gaur Gum, Gaur Seed, Gaur, Jeera, Kapas, Maize, Menta Oil, Mustard Oil, Peas, Pepper, Potato, Rubber, Soya Bean, Soya Oil, Sugar, Turmeric and Wheat.

3. METHODOLOGY

Johansen's (1988) cointegration approach and Vector Error Correction Model (VECM) have been employed to investigate the price discovery process in spot and futures market of Agriculture commodities in India. Before doing cointegration analysis, it is necessary to test the stationary of the series. The Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests were employed to infer the stationary of the series. If the series are non-stationary in levels and stationary in differences, then there is a chance of cointegration relationship between them which reveals the long-run relationship between the series. Johansen's cointegration test has been employed to investigate the long-run relationship between two variables. Besides, the causal relationship between spot and futures prices investigated by estimating the following Vector Error Correction Model (VECM) (Johansen, 1988):

$$\Delta X_t = \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \varepsilon_t ; \varepsilon t \mid \Omega_{t-1} \sim \text{distr}(0, H_t) \tag{1}$$

where X_t is the 2 × 1 vector $(S_t, F_t)'$ of log-Spot market price and log-Futures market price, respectively, Δ denotes the first difference operator, ε_t is a 2 × 1 vector of residuals $(\varepsilon_{S,t}, \varepsilon_{F,t})'$ that follow an as-yet-unspecified conditional distribution with mean zero and time-varying covariance matrix, H_t. The VECM specification contains information on both the short- and long-run adjustment to changes in X_t, via the estimated parameters Γ_i and Π, respectively.

There are two likelihood ratio tests that can be employed to identify the co-integration between the two series. The variables are cointegrated if and only if a single cointegrating equation exists. The first statistic λ_{trace} tests the number of cointegrating vectors is zero or one, and the other λ_{max} tests whether a single cointegrating equation is sufficient or if two are required. In general, if r cointegrating vector is correct. The following test statistics can be constructed as:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} 1n\left(1-\hat{\lambda}_i\right) \tag{2}$$

$$\lambda_{max}(r, r+1) = -T1n\left(1-\hat{\lambda}_{r+i}\right) \tag{3}$$

where $\hat{\lambda}_i$ are the eigen values obtained from the estimate of the P matrix and T is the number of usable observations. The λ_{trace} tests the null that there are at most r cointegrating vectors, against the alternative that the number of cointe-grating vectors is greater than r and the λ_{max} tests the null that the number of cointegrating vectors is r, against the alternative of r + 1. Critical values for the λ_{trace} and λ_{max} statistics are provided by Osterwald-Lenum (1992).

Johansen and Juselius (1990) showed that the coefficient matrix Π contains the essential information about the relationship between S_t and F_t. Specifically, if rank (Π) = 0, then Π is 2 × 2 zero matrix implying that there is no cointegration relationship between S_t and $F_{t,t-n}$. In this case the VECM reduces to a VAR model in first differences. If Π has a full rank, that is rank (Π) = 2, then all variables in X_t are $I(0)$ and the appropriate modelling strategy is to estimate a VAR model in levels. If Π has a reduced rank, that is rank (Π) = 1, then there is a single cointegrating relationship between S_t and F_t, which is given by any row of matrix Π and the expression ΠX_{t-1} is the error correction term. In this case, Π can be factored into two separate matrices α and β, both of dimensions 2 × 1, where 1 represents the rank of Π, such as $\Pi = \alpha\beta'$, where β′ represents the vector of cointegrating parameters and α is the vector of error-correction coefficients measuring the speed of convergence to the long-run steady state.

If spot and futures prices are cointegrated then causality must exist in at least one direction (Granger, 1988). Granger causality can identify whether two variables move one after the other or contemporaneously. When they move contemporaneously, one provides no information for characterising the other. If "*X* causes *Y*", then changes in *X* should precede changes in *Y*. Consider the VECM specification of Equation (1), which can be written as follows:

$$\Delta S_t \sum_{i=1}^{p-1} a_{S,i} \Delta S_{t-\mathrm{i}} + \sum_{i=1}^{p-1} b_{S,i} \Delta F_{t-i} + a_S z_{t-1} + \varepsilon_{S,t} \quad (4)$$

$$\Delta S_t \sum_{i=1}^{p-1} a_{F,i} \Delta S_{t-\mathrm{i}} + \sum_{i=1}^{p-1} b_{F,i} \Delta F_{t-i} + a_F z_{t-1} + \varepsilon_{F,t} \quad (5)$$

where $a_{S,i}$, $b_{S,i}$, $a_{F,i}$, $b_{F,i}$ are the short-run coefficients, $z_{t-1} = \beta' X_{t-1}$ is the error- correction term which measures how the dependent variable adjusts to the previous period's deviation from long-run equilibrium from equation (1), and $\varepsilon_{S,t}$ and $\varepsilon_{F,t}$ are residuals.

In the above equations of Vector Error Correction Model, the unidirectional causality from Futures-to-Spot price (F_t Granger causes S_t) requires:

(i) that some of the $b_{s,i}$ coefficients, $i = 1, 2, \ldots, p-1$, are non zero and/or

(ii) a_S, the error-correction coefficient in Equation (4), is significant at conventional levels. Similarly, unidirectional causality from Spot-to-Futures price (S_t Granger causes F_t) requires:

  (i) that some of the $a_{F,i}$ coefficients, $i = 1, 2, ..., p-1$, are non zero and/or

  (ii) a_F is significant at conventional levels.

If both variables Granger cause each other, then it is said that there is a two-way feedback relationship between S_t and F_t (Granger, 1988). These hypotheses can be tested by applying Wald tests on the joint significance of the lagged estimated coefficients of ΔS_{t-i} and ΔF_{t-i}. When the residuals of the error-correction equations exhibit heteroskedasticity, the t-statistics are adjusted by White (1980) heteroskedasticity correction.

As we are interested in knowing how volatility responds to good and bad news, we apply EGARCH specification popularized by Nelson (1991). Besides the EGARCH representation was employed to capture the leverage effect found in the returns series, and to avoid imposing non-negativity restrictions on the values of the GARCH parameters to be estimated. Specifically, we model commodity returns as follows:

$$R_t = \alpha_0 + \sum_{i=1}^{r} \alpha i R_{t-i} + \xi_{st,ft} + \varepsilon_t, \tag{6}$$

where,

$$\log(\sigma_t^2) = \exp\left(a_0 + \sum_{i=1}^{q} a_i g(z_{t-i}) + \sum_{i=1}^{p} b_i \log(\sigma_{t-i}^2)\right) \tag{7}$$

$$g(z_t) = \theta z_t + \{|z_t| - E|z_t|\} \tag{8}$$

where R_t is commodity returns, ε_t is the stochastic error, Ω_{t-1} is the information set at time $t - 1$, σ_t^2 is the conditional (time-varying) variance, and z_t is the standardized residuals (ε_t/σ_t). Conditional on Ω_{t-1}, ε_t is assumed to be normally distributed with a zero mean and variance σ_t^2.

Equation (6) (conditional mean equation) is specified as an Autoregressive process of order $r[AR(r)]$, following Theodossiou and Lee (1993), and Karolyi (1995). Although the article focuses more on volatility spillovers (second moment) than cointegration (first moment), the error correction term must be included in the conditional mean equation. Otherwise, the model will be misspecified and the residuals obtained in the first step (and, consequently, the volatility spillover results) will be biased. Thus, $\xi_{s,ft}$ represents the unautocorrelated residuals of spot and futures market obtained from equation (4) and (5), respectively. To specify the lag length r for each return series, the autocorrelation and partial autocorrelation functions of each series are considered, and residuals from the mean equations are then tested for whiteness using the Ljung-Box statistics. For the study period, it was found that two lags are needed for each return series to yield uncorrelated residuals.

Equation (7) (conditional variance equation) reflects the EGARCH (p, q) representation of the variance of ε_t. According to the EGARCH representation, the variance is conditional on its own past values as well as on past values of a function of z_t, the standardized residuals (ε_t/σ_t). The persistence of volatility implied by Equation (7) is measured by $\sum_{i=1}^{p} b_i$. The unconditional variance is finite if $\sum_{i=1}^{p} b_i > 1$. In Equation (8), the second term captures the ARCH effect, an effect similar to the idea behind the GARCH specification. The parameter θ allows for this ARCH effect to be asymmetric[3]. A negative and statistically significant θ indicates that a leverage effect exists. Lag truncation lengths, p and q, are determined using Likelihood Ratio (LR) tests of alternative specifications. Based on these tests, we employed EGARCH (1,1) models.

In this study, the univariate EGARCH (1,1) model is used to test for volatility spillovers between two markets,

(a) from spot to futures market and

(b) from futures to spot market.

To test for spillovers from spot to futures market, the most recent squared residuals from the conditional mean-conditional variance formulation of the spot market are introduced as an exogenous variable in the conditional variance equation of the futures market. Thus, the conditional variance equation becomes:

$$\log(\sigma^2_{f,t}) = \exp\{(a_0 + a_1 g(z_{f,t-1}) + b_1 \log(z_{f,t-1}) + s_1 \log(U_{s,t})\} \quad (9)$$

where $U_{s,t}$ is the contemporaneous squared residuals (from the AR(1)-EGARCH(1,1) model) for spot. $z_{f,t-1}$ are the lagged standardized residuals futures market. Existence of volatility spillovers is indicated by the statistical significance of s_1.

The sample used in the study consists of twenty-five individual agriculture commodities which are most actively traded on National Commodity Derivatives Exchange (NCDEX), Mumbai. The period of study is from 15th January 2004 to 31st March 2015. However the data period varies across commodities owing to their late introduction on trading exchanges and the fact that some agricultural commodities were banned from trading for a certain period to curb speculative impacts which according to policy makers could have triggered high inflation. The data comprises daily closing spot and futures prices of the selected twenty-five individual agriculture commodities, *viz.* Barley, Castor Seeds, Channa, Chilli, Corriander, Cotton Seed Oil Cake, Cotton, Crude Palm Oil, Gaur Gum, Gaur Seed, Gaur, Jeera, Kapas, Maize, Menta Oil, Mustard Oil, Peas, Pepper, Potato, Rubber, Soya Bean, Soya Oil, Sugar, Turmeric and Wheat. All the required data information for the study has been retrieved from the website of National Commodity Derivatives Exchange (NCDEX), Mumbai. The list of sample commodities as well as their data period is given in the following Table 1. Throughout this paper, spot and futures market returns are defined as continuously compounded or log returns (hereafter returns) at time t, R_t, calculated as follows:

$$R_t = \log(P_t / P_{t-1}) = \log P_t - \log P_{t-1} \quad (10)$$

where P_t and P_{t-1} are the daily closing prices of the agriculture commodity futures contract and its corresponding underlying spot market at days, t and $t-1$, respectively.

Table 1
List of Sample Commodities Selected for the Study

S. No.	Name of the Agriculture Commodity	Study Period
1.	Barley	29th december 2006 to 31st march 2015
2.	Caster seeds	25th august 2006 to 31st march 2015
3.	Channa	1st january 2005 to 31st march 2015
4.	Chilli	10th november 2005 to 21st january 2015
5.	Corriander	11th august 2008 to 31st march 2015
6.	Cotton seed oil cake	16th december 2005 to 31st march 2015
7.	Cotton	1st january 2009 to 31st march 2015
8.	Crude palm oil	15th january 2004 to 31st march 2015
9.	Gaur	10th december 2007 to 31st march 2015
10.	Gaur gum	27th july 2004 to 27th march 2012
11.	Gaur seed	12th april 2004 to 27th march 2012
12.	Jeera	3rd february 2005 to 31st march 2015
13.	Kapas	30th march 2007 to 31st march 2015
14.	Maize	7th february 2005 to 22nd june 2013
15.	Menta oil	29th august 2005 to 29th april 2011
16.	Mustard oil	10th november 2010 to 31st march 2015
17.	Peas	1st june 2005 to 18th december 2009
18.	Pepper	1st january 2005 to 20th may 2013
19.	Potato	9th march 2009 to 30th september 2013
20.	Rubber	29th november 2007 to 17th april 2014
21.	Soya bean	3rd november 2005 to 31st march 2015
22.	Soya oil	15th january 2004 to 31st march 2015
23.	Sugar	1st january 2008 to 19th september 2014
24.	Turmeric	1st january 2005 to 31st march 2015
25.	Wheat	2nd January 2006 to 31st March 2015

4. EMPIRICAL FINDINGS

As a preliminary step, Table 2 presents the results of descriptive statistics of spot and futures market returns of each individual commodities that belongs to Agriculture sector of an economy. The table result depicts that the futures markets provides relatively high returns than the spot markets in the case of majority of the underlying commodities. The values of standard deviation indicate that the volatility nature of all underlying commodities was found to be higher. Further, the table results reveal that the skewness statistics of futures and spot market returns of all agriculture commodities are significantly different from zero *i.e.* they are skewed either to the right or to the left. Also, the excess kurtosis values of all futures and spot return series of selected commodities are fat-tailed or leptokurtic compared to the normal distribution. In addition, the Jarque-Bera test statistics indicate that the null hypothesis of normality of return series of all selected agriculture commodities had been rejected at one per cent significance level. Hence, it can be concluded that the futures and spot market return series of all selected commodities were significantly departed from normality.

Table 2
Descriptive Statistics for Agriculture Commodity Spot and Futures Markets

	Barley		*Castor seeds*		*Channa*		*Chilli*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Mean	0.000147	0.000144	0.000212	0.000205	0.000372	0.000409	0.000503	0.000557
Median	0.00000	0.00000	0.00042	0.00000	0.00000	0.00000	–0.00024	0.00000
Maximum	0.12710	0.37590	0.09697	0.09285	0.07390	0.14220	0.14973	0.38306
Minimum	–0.20063	–0.06010	–0.13149	–0.16918	–0.11067	–0.22542	–0.46483	–0.36514
Std. Dev.	0.01147	0.01587	0.01556	0.01860	0.01369	0.01791	0.01860	0.03143
Skewness	–2.28949	7.35733	–0.20195	–0.61156	–0.11382	–1.50667	–7.43883	1.51834
Kurtosis	65.1153	161.223	12.3605	14.5160	7.33396	40.4737	229.200	48.6895
Jarque-Bera	331355	2156879	4879.31	7454.61	1989.45	149286.6	3890496	158741
Statistics	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	Corriander		*Cotton Seed Oil Cake*		*Cotton*		*Crude Palm Oil*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Mean	–8.72E-05	6.57E-05	0.000673	0.000645	–0.000509	–0.000512	2.92E-05	6.75E-05
Median	–0.000357	0.00000	0.00000	0.00000	0.00024	0.00000	0.00000	0.00000
Maximum	0.14706	0.12665	0.68593	0.71225	0.09378	0.09215	0.09601	0.22461
Minimum	–0.12649	–0.40562	–0.13213	–0.32212	–0.69495	–0.65024	–0.11134	–0.14897
Std. Dev.	0.01756	0.02282	0.01906	0.02251	0.02960	0.02854	0.00947	0.01109
Skewness	0.43165	–2.57469	18.3006	10.4851	–20.6727	–18.8648	–0.01464	7.54376
Kurtosis	10.5081	62.3130	652.963	413.519	486.875	431.817	18.7409	177.133
Jarque-Bera	4136.3	256684	4571652	1822729	6131973	4818002	32686.2	4030078
Statistics	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	Gaur Gum		*Gaur Seed*		*Gaur*		*Jeera*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Mean	0.001294	0.001208	0.001338	0.001304	0.000432	0.000361	0.000273	0.000260
Median	0.00067	0.00000	0.00071	0.00000	0.00010	0.00000	–0.00044	–0.00054
Maximum	0.12954	0.22995	0.12379	0.15584	0.15095	0.18090	0.30441	0.18018
Minimum	–0.21044	–0.24651	–0.19861	–0.23868	–0.13123	–0.15629	–0.30319	–0.05810
Std. Dev.	0.01901	0.02117	0.01786	0.02093	0.01232	0.01474	0.01165	0.01733
Skewness	–0.45420	0.12479	–0.30340	0.08268	1.93771	2.34703	0.60229	1.50296
Kurtosis	14.5598	18.3885	16.8741	14.3406	49.1795	52.3587	333.082	13.8847
Jarque-Bera	12902	22729.5	19077	12724.3	181201	207420	12720617	14887
Statistics	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	Kappas		*Maize*		*Menta Oil*		*Mustard Oil*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Mean	0.000973	0.000907	0.000463	0.000422	0.000617	0.000507	0.000149	0.000201
Median	0.00000	0.00000	0.00026	0.00000	0.00000	0.00000	0.00033	0.00000
Maximum	0.65365	0.61333	0.92525	0.17347	0.11778	0.26172	0.05518	0.07342

Cont. table 2

	Barley		*Castor seeds*		*Channa*		*Chilli*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Minimum	–0.19955	–0.23734	–0.82000	–0.12736	–0.09770	–0.15808	–0.08005	–0.09765
Std. Dev.	0.03526	0.03977	0.02711	0.01560	0.01812	0.02227	0.00833	0.01107
Skewness	11.8141	8.27135	5.24958	1.51920	0.13778	1.52894	–0.71790	–0.23978
Kurtosis	221.332	124.971	963.350	29.5293	9.39076	24.4999	13.5214	14.4922
Jarque-Bera	1097173	344676	87511023	67649	2603.3	30005.4	5647.5	6626.1
Statistics	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

	Peas		*Pepper*		*Potato*		*Soya Bean*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Mean	0.000215	0.000350	0.000656	0.000614	0.000203	0.000219	0.000235	0.000239
Median	0.00000	0.00000	0.00040	0.00000	0.00000	0.00000	0.00068	0.00000
Maximum	0.07883	0.13699	0.07226	0.17786	0.88296	0.66075	0.05041	0.10153
Minimum	–0.04731	–0.13999	–0.07955	–0.13529	–0.82186	–0.85446	–0.24174	–0.35697
Std. Dev.	0.00909	0.01443	0.01064	0.01807	0.04133	0.04529	0.01251	0.01542
Skewness	1.70947	0.89284	0.26676	1.09083	2.03706	–2.80160	–3.92459	–5.18490
Kurtosis	15.1784	26.4203	8.49145	14.4192	388.043	193.998	63.4799	112.449
Jarque-Bera	8586.8	29607	3071.9	13639.7	5819797	1433083	494219	1606024
Statistics	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

	Soya Oil		*Sugar*		*Turmeric*		*Wheat*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
Mean	0.000199	0.000169	0.000542	0.000516	0.000464	0.000504	0.000277	0.000277
Median	0.00000	6.79E–05	–0.00026	–0.00031	–0.00024	0.00000	0.00016	0.00000
Maximum	0.04394	0.07084	0.09089	0.13623	0.11365	0.30727	0.08287	0.10921
Minimum	–0.28795	–0.27537	–0.18546	–0.11533	–0.13206	–0.40863	–0.12013	–0.23025
Std. Dev.	0.00986	0.01213	0.00992	0.01292	0.01543	0.02794	0.00892	0.01292
Skewness	–9.61885	–5.29644	–2.84919	2.86705	0.78222	–0.76452	–1.38298	–3.36091
Kurtosis	290.331	116.430	94.0534	35.0760	14.3558	52.5565	32.3763	78.8162
Jarque-Bera	8776683	1373587	518812	66182	12089	226153	76433	508601
Statistics	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

	Rubber	
Statistics	*Spot Returns*	*Futures Returns*
Mean	0.000250	0.000232
Median	0.00054	0.00000
Maximum	0.07834	0.49241
Minimum	–0.67435	–0.56894
Std. Dev.	0.01900	0.02402
Skewness	–26.4953	0.36893
Kurtosis	941.375	344.912
Jarque–BeraStatistics	62239880(0.0000)	8236931(0.0000)

Notes: Figures in ( ) parentheses are Probability Values.

The unit root property of the data series is crucial for the cointegration and causality analyses. The standard Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are employed to examine stationary property of the selected data series. Table 3 depicts the results of Augmented Dickey-Fuller and Phillips-Perron tests for the spot and futures markets price series of the each underlying agriculture commodities. Both the unit root test results shows that the price series of the respective underlying commodities are stationary at their first difference, indicating that the spot and futures price series of each respective commodities are integrated at order one, *i.e.*, *I*(1).

Table 3
Results of Unit Root Test

		Augmented Dickey–Fuller Test Statistics		*Phillips–Perron Test Statistics*	
Name of the Commodity	*Market*	*Level*	*First Difference*	*Level*	*First Difference*
Barley	Spot	–1.69	–42.98*	–1.82	–43.28*
	Futures	–2.08	–43.90*	–2.10	–44.00*
Castor Seeds	Spot	–2.38	–26.49*	–2.39	–30.33*
	Futures	–2.70	–32.38*	–2.67	–32.27*
Channa	Spot	–1.98	–35.71*	–2.01	–45.67*
	Futures	–2.29	–49.95*	–2.42	–50.14*
Chilli	Spot	–2.17	–33.46*	–2.18	–33.32*
	Futures	–2.56	–39.98*	–2.40	–40.03*
Corriander	Spot	–1.33	–34.67*	–1.57	–35.55*
	Futures	–1.29	–37.01*	–1.83	–38.03*
Cotton Seed Oil Cake	Spot	–1.26	–47.60*	–1.35	–48.05*
	Futures	–1.23	–51.17*	–1.27	–51.13*
Cotton	Spot	–0.87	–25.36*	–0.85	–25.36*
	Futures	–0.80	–24.94*	–0.80	–24.94*
Crude Palm Oil	Spot	–1.89	–31.23*	–2.12	–48.73*
	Futures	–1.31	–55.96*	–1.33	–55.97*
Gaur Gum	Spot	–2.81	–42.91*	–0.42	–42.73*
	Futures	–2.75	–42.90*	–0.44	–42.78*
Gaur Seed	Spot	–0.96	–31.48*	1.44	–32.08*
	Futures	–1.00	–32.42*	1.48	–31.09*
Gaur	Spot	–2.18	–45.54*	0.35	–46.18*
	Futures	–2.21	–42.55*	0.34	–43.22*
Jeera	Spot	–1.26	–32.76*	0.96	–31.22*
	Futures	–1.27	–37.77*	0.94	–35.20*
Kapas	Spot	–2.84	–27.76*	0.02	–22.76*
	Futures	–2.80	–23.83*	0.02	–27.72*
Maize	Spot	–2.69	–41.70*	–0.01	–42.34*
	Futures	–2.65	–42.66*	–0.02	–40.63*
Menta Oil	Spot	–1.62	–31.53*	0.26	–31.66*
	Futures	–1.64	–31.59*	0.23	–29.69*

Cont. table 3

Table 3
Results of Unit Root Test

		Augmented Dickey–Fuller Test Statistics		*Phillips–Perron Test Statistics*	
Name of the Commodity	*Market*	*Level*	*First Difference*	*Level*	*First Difference*
Mustard Oil	Spot	–1.61	–42.72*	1.51	–41.60*
	Futures	–1.64	–32.69*	1.53	–36.62*
Peas	Spot	–2.01	–31.71*	0.93	–37.94*
	Futures	–2.06	–41.68*	0.98	–42.80*
Pepper	Spot	–1.87	–51.92*	–0.17	–55.73*
	Futures	–1.77	–54.86*	–0.26	–53.89*
Potato	Spot	–1.42	–33.78*	0.04	–37.48*
	Futures	–1.47	–32.82*	0.02	–39.53*
Rubber	Spot	–2.02	–29.87*	0.56	–28.05*
	Futures	–2.01	–24.84*	0.55	–26.17*
Soya Bean	Spot	–1.96	–45.23*	0.90	–42.97*
	Futures	–1.97	–42.26*	0.89	–41.98*
Soya Oil	Spot	–1.57	–33.25*	1.04	–32.53*
	Futures	–1.58	–32.29*	1.00	–31.54*
Sugar	Spot	–2.37	–31.39*	–2.36	–31.88*
	Futures	–2.49	–38.34*	–2.45	–38.44*
Turmeric	Spot	–0.75	–35.20*	–0.95	–38.04*
	Futures	–1.24	–45.87*	–1.33	–45.96*
Wheat	Spot	–1.46	–37.80*	–1.50	–38.07*
	Futures	–2.30	–46.54*	–2.29	–46.55*

Notes: *– indicates significance at one per cent level. Optimal lag length is determined by the Schwarz Information Criterion (SIC) and Newey-West Criterion for the Augmented Dickey-Fuller Test and Phillips-Perron Test respectively.

Johansen's Cointegration test is done to examine the presence of long-run relationship between spot and futures market prices of underlying commodities of agriculture sector and its results are presented in Table 4. The table result of Johansen's maximum Eigen (λ_{max}) and Trace (λ_{trace}) statistics indicates the presence of one cointegrating vector between the futures and spot market prices at 5% level in case of each selected individual commodities of agriculture sector, respectively. The Johansen's cointegration test confirms the existence of long-run relationship between the spot and futures prices of each underlying commodities in India.

Existence of long-run relationship between two markets has very important implications for the traders in futures market. Existence of cointegration suggests that although both markets may be in disequilibrium during the short-run but such deviations are very quickly corrected through arbitrage process and the hedgers may take long-run positions to hedge market risk to the maximum extent. In order to check whether short-run disequilibrium exists, Vector Autoregression (VAR) based on VECM has been applied. Kroner and Sultan (1993) shows that if the spot and futures prices

Table 4
Results of Johansen's Cointegration Test

Name of the Commodities	*Vector (r)*	*Trace Statistics (l_{trace})*	*5% critical value for l_{trace} test*	*Max-Eigen Statistics (l_{max})*	*5% critical value for l_{max} test*	*Remarks*
Barley	H_0: $r = 0$	17.9368**	15.4947	15.595**	14.2646	*Cointegrated*
	H_1: $r \geq 1$	3.34110	3.84146	3.34117	3.84146	
Castor Seeds	H_0: $r = 0$	32.6627**	15.4947	26.3069**	14.2646	*Cointegrated*
	H_1: $r \geq 1$	3.35577	3.84146	3.35577	3.84146	
Channa	H_0: $r = 0$	35.1133**	25.8721	29.3739**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	5.73940	12.5179	5.73940	12.5179	
Chilli	H_0: $r = 0$	59.5527**	25.8721	48.9123**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	10.6404	12.5179	10.6404	12.5179	
Corriander	H_0: $r = 0$	46.7492**	25.8721	33.6385**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	10.1106	12.5179	10.1106	12.5179	
Cotton Seed Oil Cake	H_0: $r = 0$	55.4224**	25.8721	47.6751**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	7.74730	12.5179	7.74730	12.5179	
Cotton	H_0: $r = 0$	40.4555**	25.8721	36.8904**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	3.56508	12.5179	3.56508	12.5179	
Crude Palm Oil	H_0: $r = 0$	27.5288**	25.8721	20.4371**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	4.09175	12.5179	4.09175	12.5179	
Gaur Gum	H_0: $r = 0$	127.806**	25.8721	89.5151**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	8.29105	12.5179	8.29105	12.5179	
Gaur Seed	H_0: $r = 0$	118.493**	25.8721	86.7348**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	11.7585	12.5179	11.7585	12.5179	
Gaur	H_0: $r = 0$	44.8853**	25.8721	35.1706**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	9.71468	12.5179	9.71468	12.5179	
Jeera	H_0: $r = 0$	149.389**	25.8721	143.370**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	6.01904	12.5179	6.01904	12.5179	
Kapas	H_0: $r = 0$	52.5336**	25.8721	48.2649**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	4.26874	12.5179	4.26874	12.5179	
Maize	H_0: $r = 0$	32.5120**	25.8721	24.8858**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	7.62619	12.5179	7.62619	12.5179	
Menta Oil	H_0: $r = 0$	29.7367**	25.8721	22.8722**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	11.0426	12.5179	10.5173	12.5179	
Mustard Oil	H_0: $r = 0$	19.9905**	25.8721	20.5373**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	1.45323	12.5179	5.45323	12.5179	
Peas	H_0: $r = 0$	39.9905**	25.8721	34.5373**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	5.45323	12.5179	5.45323	12.5179	
Pepper	H_0: $r = 0$	149.049**	25.8721	143.232**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	5.81705	12.5179	5.81705	12.5179	
Potato	H_0: $r = 0$	28.7821**	25.8721	22.0137**	19.3870	*Cointegrated*
	H_1: $r \geq 1$	6.76844	12.5179	6.76844	12.5179	

Cont. table 4

Rubber	H_0: $r = 0$	27.5934**	25.8721	20.5756**	19.3870	*Cointegrated*
	$H_{1:}$ $r \geq 1$	10.1885	12.5179	10.6785	12.5179	
Soya Bean	H_0: $r = 0$	67.5042**	25.8721	22.3577**	19.3870	*Cointegrated*
	$H_{1:}$ $r \geq 1$	0.74143	12.5179	11.4576	12.5179	
Soya Oil	H_0: $r = 0$	49.7934**	25.8721	23.7843**	19.3870	*Cointegrated*
	$H_{1:}$ $r \geq 1$	1.08465	12.5179	10.7853	12.5179	
Sugar	H_0: $r = 0$	30.8967**	25.8721	24.2545**	19.3870	*Cointegrated*
	$H_{1:}$ $r \geq 1$	10.2847	12.5179	9.25781	12.5179	
Turmeric	H_0: $r = 0$	30.9861**	25.8721	20.4578**	19.3870	*Cointegrated*
	$H_{1:}$ $r \geq 1$	11.1018	12.5179	11.3476	12.5179	
Wheat	H_0: $r = 0$	29.0132**	25.8721	26.6433**	19.3870	*Cointegrated*
	$H_{1:}$ $r \geq 1$	11.1864	12.5179	11.1246	12.5179	

Notes: ** – indicates significance at five per cent level. The significant of the statistics is based on 5 per cent critical values obtained from Johansen and Juselius (1990). r is the number of cointegrating vectors. H_0 represents the null hypothesis of presence of no cointegrating vector and H_1 represents the alternative hypothesis of presence of cointegrating vector.

are cointegrated, there must be an error correction representation that includes both the short term dynamics and long term information. For the purpose, the causality between spot and futures prices for respective agriculture commodities was estimated by using the Vector Error Correction Model (VECM) and its result are depicted in Table 5.

Table 5
Results of Vector Error Correction Model

	Barley		*Castor seeds*		*Channa*		*Chilli*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ECT	–0.003633**	0.004489***	–0.013060	0.032870*	–0.009418*	–0.012002*	0.020367*	0.008768
	(0.00190)	(0.00264)	(0.00890)	(0.01113)	(0.00317)	(0.00433)	(0.00330)	(0.00582)
	[–1.91677]	[1.69952]	[–1.46755]	[2.95449]	[–2.97093]	[2.77380]	[–6.17537]	[1.50584]
ΔS_{t-1}	0.014016	0.019296	–0.036331	0.056454	–0.026130	–0.007070	0.192585*	0.062090
	(0.02312)	(0.03221)	(0.03303)	(0.04129)	(0.02096)	(0.02861)	(0.02337)	(0.04126)
	[0.60635]	[0.59905]	[–1.10010]	[1.36736]	[–1.24653]	[–0.24710]	[8.24041]	[1.50489]
ΔS_{t-2}	–	–	–	–	–	–	–	–
ΔF_{t-1}	0.083865*	0.028221	0.285171*	0.101022*	0.218828*	0.014652	0.061498*	0.059757**
	(0.01676)	(0.02335)	(0.02791)	(0.03490)	(0.01617)	(0.02208)	(0.01400)	(0.02472)
	[5.00512]	[1.20873]	[10.2161]	[2.89492]	[13.5298]	[0.66371]	[4.39150]	[2.41711]
ΔF_{t-2}	–	–	–	–	–	–	–	–
c	0.000133	0.000138	0.000165	0.000176	0.000300	0.000404	0.000367	0.000478
	(0.00025)	(0.00035)	(0.00040)	(0.00050)	(0.00026)	(0.00036)	(0.00042)	(0.00074)
	[0.52963]	[0.39340]	[0.40779]	[0.34917]	[1.14988]	[1.13472]	[0.87957]	[0.64951]
Inference	*F ↔ S (LR)* *F→S (SR)*		*S → F (LR)* *F → S (SR)*		*F ↔ S (LR)* *F → S (SR)*		*F → S (LR)* *F → S (SR)*	

Cont. table 15

	Corriandor		*Cotton Seed Oil Cake*		*Cotton*		*Crude Palm Oil*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ECT	–0.018267* (0.00354) [–5.16250]	–0.002794 (0.00479) [–0.58374]	–0.021218* (0.00333) [–6.37647]	0.007089*** (0.00397) [1.78656]	–0.326935* (0.10095) [–3.23870]	–0.188703*** (0.09850) [–1.91573]	–0.000445 (0.00163) [–0.27359]	0.008327* (0.00194) [4.28486]
ΔS_{t-1}	0.036346 (0.02751) [1.32114]	0.100141* (0.03722) [2.69087]	0.057715* (0.01960) [2.94466]	0.086843* (0.02337) [3.71575]	–0.338874** (0.16683) [–2.03123]	–0.117745 (0.16279) [–0.72329]	0.222663* (0.01809) [12.3102]	0.062399* (0.02160) [2.88847]
ΔS_{t-2}	–	–	–	–	–	–	–	–
ΔF_{t-1}	0.181049* (0.02132) [8.49009]	0.070858** (0.02885) [2.45640]	0.056813* (0.01677) [3.38810]	–0.009958 (0.02000) [–0.49800]	0.349129** (0.17318) [2.01597]	0.113001 (0.16899) [0.66869]	–0.028802*** (0.01540) [–1.87065]	–0.008647 (0.01839) [–0.47020]
ΔF_{t-2}	–	–	–	–	–	–	–	–
c	–7.84E-05 (0.00040) [–0.19521]	6.79E-05 (0.00054) [0.12503]	0.000589 (0.00037) [1.59132]	0.000574 (0.00044) [1.30067]	–0.000496 (0.00117) [–0.42353]	–0.000498 (0.00114) [–0.43579]	2.35E-05 (0.00016) [0.14265]	6.57E-05 (0.00020) [0.33459]
Inference	*F → S (LR)* *F ↔ S (SR)*		*F ↔ S (LR)* *F ↔ S (SR)*		*F ↔ S (LR)* *F → S (SR)*		*F→S (LR)* *F ↔ S (SR)*	
	Gaur Gum		*Gaur Seed*		*Gaur*		*Jeera*	
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ECT	–0.047937* (0.01263) [–3.79592]	0.052626* (0.01484) [3.54619]	–0.039523* (0.01083) [–3.64929]	0.050352* (0.01334) [3.77528]	–0.019125* (0.00325) [–5.88120]	–0.002244 (0.00407) [–0.55124]	–0.049154* (0.00475) [–10.3527]	0.012576 (0.00783) [1.60552]
ΔS_{t-1}	–0.163703* (0.02693) [–6.07903]	0.104652* (0.03164) [3.30711]	–0.118731* (0.02586) [–4.59103]	0.130008* (0.03185) [4.08223]	0.176650* (0.02272) [7.77664]	0.007434 (0.02844) [0.26139]	–0.338678* (0.01990) [–17.0220]	0.006839 (0.03282) [0.20834]
ΔS_{t-2}	–	–	–	–	0.012766 (0.02227) [0.57309]	–0.009210 (0.02789) [–0.33025]	–0.089608* (0.01926) [–4.65151]	0.020911 (0.03178) [0.65794]
ΔF_{t-1}	0.371126* (0.02458) [15.1015]	0.063604** (0.02888) [2.20245]	0.324066* (0.02260) [14.3362]	0.042427 (0.02784) [1.52414]	0.109108* (0.01853) [5.88915]	0.003183 (0.02320) [0.13722]	0.231172* (0.01279) [18.0737]	0.079282* (0.02110) [3.75715]
ΔF_{t-2}	–	–	–	–	0.019977 (0.01864) [1.07179]	–0.000460 (0.02334) [–0.01970]	0.078219* (0.01339) [5.84292]	–0.015954 (0.02209) [–0.72238]
c	0.001074* (0.00037) [2.89255]	0.001033** (0.00044) [2.36932]	0.001080* (0.00035) [3.12201]	0.001081* (0.00043) [2.53890]	0.000298 (0.00026) [1.13370]	0.000361 (0.00033) [1.09940]	0.000311 (0.00020) [1.56859]	0.000237 (0.00033) [0.72565]
Inference	*F ↔ S (LR)* *F ↔ S (SR)*		*F ↔ S (LR)* *F ↔ S (SR)*		*F → S (LR)* *F → S (SR)*		*F → S (LR)* *F → S (SR)*	
	Kapas		*Maize*		*Menta Oil*		*Mustard Oil*	
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ECT	–0.030500 (0.03235) [–0.94278]	0.138614* (0.03614) [3.83561]	0.000256** (0.00012) [2.15310]	–0.000312* (6.8E-05) [–4.57170]	–0.024240* (0.00818) [–2.96398]	0.016802 (0.01022) [1.64365]	–0.007313* (0.00301) [–2.43093]	0.003382 (0.00438) [0.77260]

Cont. table 5

	Kapas		*Maize*		*Menta Oil*		*Mustard Oil*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ΔS_{t-1}	0.007424 (0.06588) [0.11269]	–0.050355 (0.07359) [–0.68422]	0.002983 (0.02099) [0.14212]	0.003586 (0.01204) [0.29788]	–0.010803 (0.03268) [–0.33058]	0.161217* (0.04085) [3.94691]	0.167996* (0.03245) [5.17787]	0.038029 (0.04721) [0.80561]
ΔS_{t-2}	–	–	–	–	–0.050410 (0.03204) [–1.57332]	0.044097 (0.04005) [1.10108]	0.008909 (0.02953) [0.30167]	–0.047746 (0.04297) [–1.11119]
ΔF_{t-1}	0.076624*** (0.02929) [1.69226]	0.122493*** (0.06624) [1.84933]	0.019577*** (0.01660) [1.73492]	0.010890 (0.02099) [0.51881]	0.199359* (0.02644) [7.53975]	0.062704*** (0.03305) [1.89727]	0.221078* (0.02254) [9.80906]	–0.022260 (0.03279) [–0.67883]
ΔF_{t-2}	–	–	–	–	–0.006187 (0.02667) [–0.23198]	–0.048563 (0.03333) [–1.45681]	–0.009948 (0.02320) [–0.42872]	0.015093 (0.03376) [0.44708]
c	0.000891 (0.00151) [0.59059]	0.000872 (0.00168) [0.51789]	0.000446 (0.00057) [0.78390]	0.000417 (0.00033) [1.27799]	0.000557 (0.00045) [1.23847]	0.000371 (0.00056) [0.65866]	8.92E-05 (0.00022) [0.40528]	0.000194 (0.00032) [0.60608]
Inference	$S \rightarrow F$ (LR) $F \rightarrow S$ (SR)		$F \leftrightarrow S$ (LR) $F \rightarrow S$ (SR)		$F \rightarrow S$ (LR) $F \rightarrow S$ (SR)		$F \rightarrow S$ (LR) $F \rightarrow S$ (SR)	
	Peas		*Pepper*		*Potato*		*Rubber*	
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ECT	–0.004085 (0.00522) [–0.78320]	0.035375* (0.00805) [4.39374]	–0.030299* (0.00459) [–6.60539]	0.000956 (0.00902) [0.10590]	–0.041984* (0.00907) [–4.62826]	–0.012426 (0.01005) [–1.23691]	0.003422 (0.00371) [0.92168]	0.018477* (0.00470) [3.93498]
ΔS_{t-1}	0.092542* (0.02847) [3.25055]	0.327420* (0.04395) [7.45055]	–0.091972* (0.02447) [–3.75781]	–0.037463 (0.04815) [–0.77806]	0.061640 (0.04089) [1.50762]	0.071634*** (0.04528) [1.68202]	0.117500* (0.02904) [4.04594]	0.071020*** (0.03673) [1.93378]
ΔS_{t-2}	–	–	0.092488* (0.02079) [4.44888]	0.028675 (0.04090) [0.70113]	–	–	–	–
ΔF_{t-1}	0.051291* (0.01791) [2.86344]	–0.128779* (0.02765) [–4.65756]	0.288815* (0.01303) [22.1652]	0.057084* (0.02563) [2.22692]	–0.015884 (0.03772) [–0.42106]	–0.029407 (0.04178) [–0.70387]	0.008344 (0.02292) [0.36401]	0.027377 (0.02899) [0.94445]
ΔF_{t-2}	–	–	0.005113 (0.01399) [0.36540]	–0.020090 (0.02753) [–0.72975]	–	–	–	–
c	0.000184 (0.00025) [0.73273]	0.000340 (0.00039) [0.87505]	0.000474** (0.00019) [2.53031]	0.000596 (0.00037) [1.61670]	0.000188 (0.00133) [0.14104]	0.000175 (0.00148) [0.11829]	0.000222 (0.00046) [0.48271]	0.000208 (0.00058) [0.35830]
Inference	$S \rightarrow F$ (LR) $F \leftrightarrow S$ (SR)		$F \rightarrow S$ (LR) $F \rightarrow S$ (SR)		$F \rightarrow S$ (LR) $S \rightarrow F$ (SR)		$S \rightarrow F$ (LR) $S \rightarrow F$ (SR)	
	Soya Bean		*Soya Oil*		*Sugar*		*Turmeric*	
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ECT	–0.024589* (0.00318) [–7.73848]	–0.000738 (0.00414) [–0.17834]	–0.028620* (0.00636) [–4.50212]	0.009878 (0.00816) [1.20997]	–0.018129* (0.00703) [–2.57747]	0.043984* (0.00945) [4.65566]	–0.011606* (0.00303) [–3.82690]	0.018855* (0.00579) [3.25795]

Cont. table 5

	Soya Bean		*Soya Oil*		*Sugar*		*Turmeric*	
Statistics	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*	*Spot Returns*	*Futures Returns*
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
ΔS_{t-1}	0.136330* (0.01935) [7.04536]	0.063404** (0.02519) [2.51671]	–0.005381 (0.02582) [–0.20838]	0.034621 (0.03316) [1.04398]	0.130558* (0.02832) [4.60992]	–0.048348 (0.03804) [–1.27103]	0.191304* (0.02401) [7.96926]	0.083969*** (0.04581) [1.83293]
ΔS_{t-2}	0.022609 (0.01855) [1.21888]	–0.001580 (0.02415) [–0.06543]	–0.033235 (0.02441) [–1.36166]	–0.045572 (0.03134) [–1.45393]	–0.004392 (0.02740) [–0.16025]	0.062056*** (0.03681) [1.68597]	0.043727*** (0.02313) [1.89084]	0.008698 (0.04413) [0.19708]
ΔF_{t-1}	0.152716* (0.01526) [10.0093]	–0.003569 (0.01986) [–0.17969]	0.213336* (0.02052) [10.3956]	0.030314 (0.02635) [1.15029]	0.136205* (0.02121) [6.42243]	0.040478 (0.02848) [1.42104]	0.082640* (0.01276) [6.47543]	0.014702 (0.02436) [0.60366]
ΔF_{t-2}	–0.016494 (0.01543) [–1.06864]	0.020651 (0.02009) [1.02766]	0.047955* (0.02074) [2.31271]	0.051286*** (0.02663) [1.92601]	0.029292 (0.02135) [1.37193]	0.042136 (0.02868) [1.46933]	–0.004510 (0.01278) [–0.35294]	0.012771 (0.02439) [0.52371]
c	0.000164 (0.00021) [0.78245]	0.000221 (0.00027) [0.80929]	0.000169 (0.00019) [0.90000]	0.000164 (0.00024) [0.68180]	0.000379 (0.00025) [1.53001]	0.000452 (0.00033) [1.35972]	0.000315 (0.00031) [1.01214]	0.000452 (0.00059) [0.75993]
Inference	*F → S (LR)* *S → F (SR)*		*F → S (SR)* *F ↔ S (LR)*		*F → S (LR)* *F ↔ S (SR)*		*F ↔ S (LR)* *F ↔ S (SR)*	

	Wheat	
	ΔS_t	ΔF_t
ECT	–0.017700* (0.00323) [–5.47337]	0.006699 (0.00485) [1.38069]
ΔS_{t-1}	0.156399* (0.02224) [7.03316]	0.051943 (0.03337) [1.55681]
ΔS_{t-2}	–0.042438** (0.02191) [–1.93716]	–0.047271 (0.03287) [–1.43810]
ΔF_{t-1}	0.075277* (0.01516) [4.96566]	–0.017897 (0.02275) [–0.78683]
ΔF_{t-2}	0.041938* (0.01521) [2.75719]	–0.042865*** (0.02282) [–1.87828]
c	0.000203 (0.00019) [1.08158]	0.000287 (0.00028) [1.01856]
Inference	*F → S (LR)* *F → S (SR)*	

Notes: SR and LR stands for Short-run and Long-run, respectively. Optimal lag length is determined by the Schwarz Information Criterion (SIC), F_t and S_t are the Futures and Spot market prices respectively, *, ** and *** denote the significance at the one, five and ten per cent level, respectively. [ ] and ( ) - Parenthesis shows t-statistics and standard error, respectively.

The estimates of Vector Error Correction Model show the mixed evidence. The findings of underlying commodities of Agriculture reveal that long-run unidirectional causation runs from futures to spot market price in the case of twelve underlying commodities, *viz.* Chilli, Corriander, Crude Palm Oil, Gaur, Jeera, Menta Oil, Mustard Oil, Pepper, Potato, Soya Bean, Soya Oil and WHEAT. This is followed by the feedback relationship between futures and spot market prices in the case of nine selected agriculture commodities in the long-run *viz.*, Barley, Channa, Cotton Seed Oil Cake, Cotton, Gaur Gum, Gaur Seed, Maize, Sugar and Turmeric and one-way causal linkage from spot to futures market prices in the long-run for Caster Seed, Kapas, Peas and Rubber.

Besides, there exists one-way causal linkage from futures market to spot market prices in the short-run for thirteen agriculture commodities, *viz.*, Barley, Castor Seeds, Channa, Chilli, Cotton, Jeera, Kapas, Maize, Menta Oil, Mustard Oil, Pepper, Soya Oil and Wheat. This indicates that information gets reflected first in the futures prices and then it is transmitted to spot market prices of the thirteen agriculture commodities. The table result also confirms the short-run feedback relationship between futures and spot markets for eight agriculture commodities, *viz.*, Corriander, Cotton Seed Oil Cake, Crude Palm Oil, Gaur Gum, Gaur Seed, Peas, Sugar and Turmeric. This reveals that both the spot and futures markets prices of these eight commodities play the leading role through price discovery process and said to be informationally efficient and react more quickly to each other.

Moreover, the table result confirms the one-way causal linkage from spot to futures market prices in the case of three underlying Agriculture commodities, *viz.*, Potato, Rubber and Soya Bean. This implies that spot market prices of these Agriculture commodities play the leading role and act as an efficient price discovery vehicle.

Regarding the examination of Volatility Spillover effects in the Indian agriculture commodity markets, Engle (1982) ARCH-LM test statistics was conducted in order to test the null hypothesis of no ARCH effects and its results are reported in the Table-6. The test statistics are highly significant at one percent levels, confirming the existence of significant ARCH effects on the futures and spot return data series of all selected underlying commodities of agriculture sector.

The spot and futures return series of all selected underlying commodities of Agriculture appear to be best described by an unconditional leptokurtic distribution and possesses significant ARCH effects which is confirmed by ARCH LM test statistics, *i.e.* volatility clustering. This suggests that the Bivariate EGARCH model is capable with generalised error distribution (GED) is deemed fit for modeling the spot and futures return volatility of these commodities, as it sufficiently captures the volatility clustering and heteroscedastic effects. Table 7 shows the estimates of Bivariate EGARCH model to determine the volatility spillover mechanism takes place between spot and futures commodity markets of respective commodities that belongs to Agriculture sector.

Table 6
ARCH LM Test Results for Spot and Futures Agriculture Commodity Markets

	ARCH LM Statistics			
Name of the Commodity	*Spot Returns*	*Prob. Value*	*Futures Returns*	*Prob. Value*
Barley	45.324	0.000	53.975	0.000
Caster Seeds	630.67	0.000	46.567	0.000
Channa	664.65	0.000	119.20	0.000
Chilli	99.636	0.000	679.99	0.000
Corriander	45.324	0.000	53.975	0.000
Cotton Seed Oil Cake	630.67	0.000	46.567	0.000
Cotton	664.65	0.000	119.20	0.000
Crude Palm Oil	99.636	0.000	679.99	0.000
Gaur Gum	45.324	0.000	53.975	0.000
Gaur Seed	630.67	0.000	46.567	0.000
Gaur	664.65	0.000	119.20	0.000
Jeera	99.636	0.000	679.99	0.000
Kapas	45.324	0.000	53.975	0.000
Maize	630.67	0.000	46.567	0.000
Menta Oil	664.65	0.000	119.20	0.000
Mustard Oil	99.636	0.000	679.99	0.000
Peas	45.324	0.000	53.975	0.000
Pepper	630.67	0.000	46.567	0.000
Potato	664.65	0.000	119.20	0.000
Rubber	99.636	0.000	679.99	0.000
Soya Bean	45.324	0.000	53.975	0.000
Soya Oil	630.67	0.000	46.567	0.000
Sugar	664.65	0.000	119.20	0.000
Turmeric	99.636	0.000	679.99	0.000
Wheat	45.324	0.000	53.975	0.000

Note: ARCH-LM is a Lagrange multiplier test for ARCH effects in the residuals (Engle, 1982).

The empirical evidence from Table 7 reveals that the GARCH effects (measured by α_i) for all the commodities are statistically significant, implying the degree of volatility persistence exists in the case of both futures and spot market returns of respective commodities that belongs to Agriculture. This result suggests that once a shock has occurred, volatility tends to persist for long periods in both the spot and futures markets of respective commodity.

The leverage effect parameters (α_i) are statistically significant for both futures and spot market returns of respective agriculture commodities, indicating existence of leverage effect. This indicates that negative shocks have a greater impact on conditional volatility than positive shocks of equal magnitude in the case of respective commodities of Agriculture. This means that volatility is higher after negative shocks (bad news) rather than after positive shocks (good news) of the same magnitude.

Table 7
Results of Bivariate EGARCH model

Name of the Commodities	*Market*	ω_i	ψ_i	α_i	γ_i	τ_i	*ARCH–LM Statistics*	*Inference*
				Agriculture				
Barley	Spot	–0.138*	–2.670*	0.665*	0.768*	–0.399*	0.0019	F → S
		(–8.843)	(–18.81)	(33.04)	(10.89)	(–22.95)	[0.9650]	
	Futures	0.094*	–0.987*	0.892*	0.089	–0.027**	6.6692	
		(6.913)	(–12.08)	(84.75)	(1.495)	(–2.357)	[0.4137]	
Castor Seeds	Spot	0.036**	–6.146*	0.220*	0.749*	–0.330*	0.0088	F → S
		(2.302)	(–27.92)	(7.344)	(4.30)	(–18.01)	[0.9249]	
	Futures	0.083**	–0.287*	0.971*	0.181	–0.074*	0.0081	
		(5.976)	(–7.885)	(23.38)	(01.49)	(–8.770)	[0.9279]	
Channa	Spot	0.0338	–0.7681*	0.9085*	0.1890*	–0.035**	1.0388	F → S
		(1.618)	(–4.342)	(37.16)	(5.951)	(–1.975)	[0.3084]	
	Futures	0.034**	–9.144*	0.128*	0.0861	–0.422*	0.1690	
		(1.992)	(–60.89)	(5.886)	(1.651)	(–14.88)	[0.6810]	
Chilli	Spot	0.0862*	–1.7767*	0.8178*	0.3333*	–0.0213*	0.6810	F → S
		(3.892)	(–6.840)	(25.23)	(8.251)	(–2.963)	[0.2777]	
	Futures	0.0423**	–1.2372*	0.8637*	0.0356	–0.0194**	1.6171	
		(1.970)	(–8.224)	(45.05)	(1.509)	(–2.036)	[0.2039]	
Corriander	Spot	0.0429**	–2.259*	0.7547*	0.3905*	–0.0156*	1.2602	F ↔ S
		(2.268)	(–12.89)	(31.74)	(18.05)	(–2.939)	[0.2793]	
	Futures	0.0762*	–0.9088*	0.8913*	0.1897*	–0.0318*	1.6563	
		(5.301)	(–6.908)	(55.57)	(9.692)	(–2.808)	[0.1166]	
Cotton Seed Oil Cake	Spot	0.0599*	–1.1850*	0.8704*	0.2211*	–0.0559*	0.5449	F ↔ S
		(3.916)	(–7.836)	(49.34)	(8.961)	(–4.483)	[0.4606]	
	Futures	0.0603*	–1.4963*	0.8398*	0.2488*	–0.0788*	0.2127	
		(3.706)	(–8.092)	(36.87)	(9.078)	(–4.924)	[0.6448]	
Cotton	Spot	0.9955*	–3.9784*	0.4914*	0.1322*	–0.0302**	0.1924	F → S
		(404.25)	(–20.63)	(15.64)	(5.774)	(–2.617)	[0.6610]	
	Futures	–0.0029	–1.4732*	0.8499*	0.0132	–0.0149**	0.4293	
		(–0.189)	(–13.45)	(66.54)	(1.217)	(–2.099)	[0.5125]	
Crude Palm Oil	Spot	0.0569*	–1.0100*	0.8893*	0.2796*	–0.0196**	0.1824	F ↔ S
		(3.778)	(–7.035)	(54.44)	(12.33)	(–1.995)	[0.6694]	
	Futures	0.0850*	–2.1386*	0.7659*	0.361*	–0.0103*	0.2890	
		(5.429)	(–12.88)	(36.27)	(14.59)	(–2.675)	[0.5910]	
Gaur Gum	Spot	0.0522*	–0.8643*	0.9054*	0.2240*	–0.030**	0.3190	F ↔ S
		(2.797)	(–7.907)	(65.87)	(10.99)	(–2.491)	[0.8653]	
	Futures	0.0449**	–0.5151*	0.9484*	0.1781*	–0.032**	1.1230	
		(2.123)	(–5.069)	(76.01)	(8.136)	(–2.521)	[0.3389]	
Gaur Seed	Spot	0.0220	–1.2449*	0.8437*	0.2645*	–0.0199**	0.0786	F ↔ S
		(1.156)	(–6.826)	(36.58)	(10.17)	(–1.964)	[0.7793]	
	Futures	0.0335	–3.0090*	0.6810*	0.3025*	–0.0120*	0.1141	
		(1.486)	(–13.43)	(18.87)	(11.96)	(–2.660)	[0.7356]	

Cont. table 7

Name of the Commodities	*Market*	ω_i	ψ_i	α_i	γ_i	τ_i	*ARCH–LM Statistics*	*Inference*
				Agriculture				
Gaur	Spot	0.0735*	–1.0753*	0.9085*	0.2985*	–0.0445*	1.3543	F → S
		(5.139)	(–11.64)	(34.91)	(17.35)	(–3.655)	[0.2133]	
	Futures	0.0233	–0.4297*	0.9576*	0.0862	–0.0448*	0.4342	
		(1.176)	(–3.567)	(28.92)	(1.232)	(–2.851)	[0.5101]	
Jeera	Spot	0.0087	–0.6533*	0.9297*	–0.026**	–0.028**	0.1955	F → S
		(0.781)	(–6.801)	(29.36)	(–2.488)	(–2.488)	[0.8994]	
	Futures	0.0681*	–0.3531*	0.9709*	0.0021	–0.0617*	0.9862	
		(3.892)	(–7.904)	(24.93)	(1.507)	(–9.189)	[0.3210]	
Kapas	Spot	0.0328	–0.9465*	0.8979*	0.2333*	–0.0215**	2.1221	F → S
		(1.633)	(–6.553)	(50.91)	(10.65)	(–2.402)	[0.1456]	
	Futures	–0.0143	–0.4613*	0.9554*	0.0305	–0.0020**	1.6785	
		(–0.9142)	(–9.0538)	(146.09)	(1.306)	(–2.2164)	[0.136]	
Maize	Spot	0.0106	–0.3772*	0.9651*	0.1840*	–0.0313*	1.4984	F → S
		(0.6824)	(–12.378)	(48.04)	(14.278)	(–3.8294)	[0.107]	
	Futures	0.0231	–0.5392*	0.9436*	0.0155	–0.0021**	1.5796	
		(1.5052)	(–8.9472)	(32.05)	(1.490)	(–2.1928)	[0.1623]	
Menta Oil	Spot	0.0671*	–3.8939*	0.5188*	0.2709*	–0.0949*	0.0013	F → S
		(2.9498)	(–8.3680)	(8.7673)	(8.9989)	(5.1441)	[0.9708]	
	Futures	0.0625*	–1.9057*	0.7879*	0.0614	–0.2343*	0.0788	
		(3.9887)	(–12.314)	(36.377)	(1.080)	(11.137)	[0.9954]	
Mustard Oil	Spot	0.1407*	–0.7275*	0.9445*	0.4124*	–0.0449*	0.0121	F → S
		(7.5457)	(–15.039)	(26.812)	(9.1984)	(–3.0510)	[0.9124]	
	Futures	0.0423**	–0.2814*	0.9772*	0.0761	–0.0307*	0.8504	
		(2.4085)	(–17.261)	(51.86)	(1.584)	(–5.5804)	[0.5138]	
Peas	Spot	0.0312	–0.2434*	0.9748*	0.0943*	–0.0538*	0.1357	F ↔ S
		(1.6921)	(–9.5480)	(48.26)	(12.436)	(–6.3748)	[0.7125]	
	Futures	0.0364**	–1.5233*	0.8286*	0.4253*	–0.0343*	0.2541	
		(2.0674)	(–15.466)	(34.858)	(21.298)	(–2.742)	[0.6142]	
Pepper	Spot	0.0598*	–0.3742*	0.9654*	0.1582 *	–0.0251*	1.2870	F → S
		(3.7889)	(–8.1060)	(38.90)	(10.292)	(–2.8031)	[0.2567]	
	Futures	0.035**	–5.444*	0.095**	0.0081	–0.204*	0.0134	
		(1.973)	(–19.24)	(1.972)	(1.586)	(–8.031)	[0.9077]	
Potato	Spot	–0.005	–0.049*	0.992*	0.098	–0.122*	0.0029	S → F
		(–0.368)	(–11.36)	(14.3)	(1.285)	(–44.35)	[0.9568]	
	Futures	0.093*	–0.656*	0.915*	0.241*	–0.103*	0.8521	
		(4.071)	(–14.03)	(13.68)	(6.680)	(–10.11)	[0.3560]	
Rubber	Spot	–0.100*	–3.791*	0.474*	0.013	–0.481*	0.0215	S → F
		(–4.768)	(–29.75)	(22.28)	(0.741)	(–20.26)	[0.8834]	
	Futures	0.064*	–1.070*	0.871*	0.327*	–0.053*	1.4360	
		(4.059)	(–14.94)	(89.21)	(4.128)	(–5.619)	[0.2193]	

Cont. table 7

Name of the Commodities	*Market*	ω_i	ψ_i	α_i	γ_i	τ_i	*ARCH–LM Statistics*	*Inference*
				Agriculture				
Soya Bean	Spot	0.0668*	–2.839*	0.666*	0.165	–0.172*	0.0175	S → F
		(4.184)	(–17.71)	(30.49)	(1.641)	(–13.40)	[0.8945]	
	Futures	0.011**	–0.323*	0.971*	0.837*	–0.004**	4.6910	
		(2.032)	(–16.13)	(371.4)	(6.78)	(–2.571)	[0.2387]	
Soya Oil	Spot	0.052*	–2.474*	0.833*	0.640**	0.167*	0.3827	F → S
		(3.280)	(–18.81)	(43.21)	(2.431)	(9.648)	[0.5361]	
	Futures	0.062*	–0.175*	0.987*	0.122	–0.012**	0.2771	
		(4.232)	(–9.966)	(500.3)	(1.391)	(–1.977)	[0.8419]	
Sugar	Spot	0.063*	–0.601*	0.952*	0.385*	–0.059*	0.2747	F ↔ S
		(4.014)	(–21.07)	(45.5)	(54.75)	(–6.186)	[0.6001]	
	Futures	0.091*	–0.314*	0.974*	0.196*	–0.008**	2.3449	
		(7.005)	(–14.27)	(61.1)	(21.06)	(–1.982)	[0.1257]	
Turmeric	Spot	0.069*	–4.249*	0.439*	0.184*	–0.028**	0.0050	F ↔ S
		(4.555)	(–6.483)	(4.973)	(7.010)	(–1.994)	[0.9434]	
	Futures	–0.056*	–4.838*	0.467*	0.910*	–0.104*	0.2362	
		(–7.868)	(–31.19)	(24.18)	(81.78)	(–8.425)	[0.6269]	
Wheat	Spot	0.117*	–0.590*	0.947*	0.345*	–0.079*	0.0032	F → S
		(6.685)	(–15.39)	(16.88)	(3.306)	(–8.629)	[0.9548]	
	Futures	0.293*	–7.789*	0.011	0.053	–0.316*	0.0059	
		(19.30)	(–148.86)	(1.457)	(1.240)	(–12.15)	[0.9387]	

Notes: Figures in ( ) parentheses are *z*-statistics. * (**) denote the significance at the one and five per cent level, respectively. Figures in [ ] indicates the probability value of ARCH LM test. ARCH-LM is the Lagrange Multiplier test for ARCH effects (Engle, 1982).

Most importantly, Table 7 result shows the mixed evidence in the case of spillover effect. The findings of underlying commodities of Agriculture reveal that spillover takes place from futures market to spot market prices in the for thirteen agriculture commodities, *viz.*, Barley, Castor Seeds, Channa, Chilli, Cotton, Jeera, Kapas, Maize, Menta Oil, Mustard Oil, Pepper, Soya Oil and Wheat. This indicates that the spillovers of certain information take place from futures market to spot market and the futures market of these commodities have the capability to expose the all new information through the channel of its new innovation.

The table result also confirms the bidirectional spillover effect exists between futures and spot markets for eight agriculture commodities, *viz.*, Corriander, Cotton Seed Oil Cake, Crude Palm Oil, Gaur Gum, Gaur Seed, Peas, Sugar and Turmeric. This reveals that both the spot and futures markets of these commodities have the capability to expose the all new information through the channel of its new innovation.

Besides, the table confirms the spillover effect takes place from spot to futures market prices in the case of three underlying Agriculture commodities, *viz.*, Potato, Rubber and Soya Bean. This implies that the spillovers of certain information take place from spot market to futures market and the spot market of these three commodities have the capability to expose the all new information through the channel of its new innovation.

To check the robustness of Bivariate EGARCH estimates for the respective commodities of Agriculture sector, the ARCH-LM (Engle, 1982) test was employed to test the absence of any further ARCH effects. As can be seen in Table 7, the ARCH-LM statistics indicate that no serial dependence persists left in squared residuals. Hence, the results suggest that Bivariate EGARCH model was reasonably well specified and most appropriate model to capture the ARCH (time-varying volatility) effects in the time series analysed for respective commodities that belong to Agriculture.

5. CONCLUSION

The Commodity market is poised to play an important role of performs two important functions of price discovery and price risk management for the development of agriculture and other sectors in the economy. Since 2002 the commodities futures market in India has experienced an unexpected boom in terms of modern exchanges, number of commodities allowed for derivatives trading as well as the value of futures trading. Commodity Futures Market plays an important role in price discovery, the information on which helps the producers to plan their activities on production, processing, storage, and marketing of commodities. The issue of Price Discovery and Volatility Spillover is of interest to traders, investors, financial economists and analysts and it have been extensively researched for mature markets with greater focus on equity markets. The research study is limited for commodity markets, especially on Agriculture sector and India in particular. This study examines the price discovery and volatility spillovers between futures and spot prices of twenty-five agricultural commodities *viz.*, Barley, Castor Seeds, Channa, Chilli, Corriander, Cotton Seed Oil Cake, Cotton, Crude Palm Oil, Gaur Gum, Gaur Seed, Gaur, Jeera, Kapas, Maize, Menta Oil, Mustard Oil, Peas, Pepper, Potato, Rubber, Soya Bean, Soya Oil, Sugar, Turmeric and Wheat, traded on National Commodity and Derivatives Exchange (NCDEX). The study uses the daily data from 15th January 2004 to 31st March 2015. The empirical results confirm the price discovery between futures and spot prices, indicating strong information transmission from futures markets to spot markets in the case of majority of Agriculture commodities. This is followed by the feedback relationship between futures and spot market prices and one-way causal linkage from spot to futures market prices. Besides, the study results suggest that the volatility spillover effects are found to be quite strong in agri-futures market. The present study concludes that India's agriculture commodity derivatives market is evolving in the right direction as futures market has started playing crucial role in the information transmission process. Another important feature of this study is that the role of spot market is strongly visible, indicating that the spot market plays equally important role *vis-à-vis* futures market in price discovery and volatility spillover process.

Note

1. If $\theta = 0$ then a positive shock has the same effect as a negative shock of the same magnitude. If $0 > \theta > -1$, a negative shock increases volatility more than a positive shock and thus, q measures the asymmetric effect of shocks on volatility. If $\theta < -1$, a negative (positive) shock actually increases (reduces) volatility.

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