ISSN No. 2454 – 1427

CDE
June 2017

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Working Paper No. 276

http://www.cdedse.org/pdf/work276.pdf

CENTRE FOR DEVELOPMENT ECONOMICS
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Abstract

With the onset of wide-ranging economic reforms in India in 1991, agents have been exposed to increased price risk in commodity markets. Futures markets are one important instrument for reducing price risk, and in this study we focus on the price discovery role of futures markets. Employing daily price data for nine crops for the period 2009-2014, we find strong causation running from futures to spot prices. Since spot prices impinge on the storage and cropping pattern decisions of farmers, our results imply that providing information on futures price to farmers on a daily basis would enable them to take more efficient decisions in the present.

Keywords: Futures markets, spot markets, primary commodities

JEL Classification: Q02, Q18 and G13

Acknowledgements

I would like to express my gratitude to Aditi Singhal, Chandan Singha, Chhaya Chanchal, Divya Gupta, Divya Tuteja, Naveen Joseph Thomas, Sanjeev Sharma, Sonal Dua and Sunil Kanwar for their feedback.

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1. Introduction

Wide-ranging economic reforms, resulting in increasing liberalisation and globalisation of markets and removal of state controls, have been undertaken in India subsequent to the economic crisis of 1991. In the changing environment, various agents have been exposed to increased price risk in commodity markets, especially in view of the opening up of the Indian economy to external forces. To cope with these changes, market-based instruments and risk management measures are required to reduce the price risk in the economy. Futures markets are one important instrument for reducing price risk (World Bank 1996).

There are two important social benefits of futures markets – price discovery, and risk management through hedging. In this study we focus on the price discovery role of futures markets. Price discovery[1] is the ability of the market to discover equilibrium prices. Price discovery refers to the use of futures prices for pricing spot market transactions (Working 1948, Lake 1978). The significance of price discovery depends on long run (cointegrating) relations between spot and futures prices (Garbede and Silver 1983).

Futures prices are the result of open and competitive trading on the floor of the exchange, and reflect the underlying supply and demand for a commodity, both in the present and the future. If a farmer, for instance, obtains advance information about the price of the product that is likely to exist at the time of harvest, he can plan his crop and

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[1] Price discovery refers to whether the equilibrium price in one market helps in determining that in another market (Edward and Ma 2003). In the context of spot and futures markets, it implies that the two markets have a long-term or cointegrating relationship, and arbitrage restores the long-term relationship in case of short-term deviations. In case of a disequilibrium, the 'dominant' market tends to stay put, while the 'satellite' market tends to adjust towards it, so that the satellite market price reflects the dominant market price with a lag (Garbede and Silver 1979).

investment accordingly (Government of India 2008). In addition, as the harvest time nears, knowledge of the price that is likely to exist in the post-harvest period can help him decide whether to sell or retain his crop at harvest time. Consequently, subject to his access to enabling factors such as warehousing, finance, etc., he would be able to exert his marketing option in a manner that would maximize his income. Thus, if causality runs from the futures to the spot market, current price formation can gain from this transmission of information, and this can benefit both producers and consumers. Further, better spatial integration of spot markets would prevent local monopolies[2], and thereby promote greater efficiency and welfare. In this way, the futures market can serve as the reference for the spot market.

One of the major reasons for establishing commodities futures markets in India in 2004 was to set up the infrastructure that would assist farmers to access the market as well-informed players. The National Agricultural Policy 2000 (NAP 2000) emphasized wider coverage of futures markets to minimize the fluctuations in commodity prices; and also for hedging price risk. The Guru committee (2001) laid emphasis on the role of futures trading for price risk management and marketing of agricultural commodities.

In the Indian context, commodity futures trading started in 2004. However, even though futures markets grew at a fast pace in the initial years, their role has been met with much scepticism and a lot of questions have been raised regarding their benefits. The Government of India formed a committee to look into the role of futures trading in the price rise of agricultural commodities in 2007. The committee claimed that there is no transmission of prices between futures and spot markets. It appears, however, that this

[2] In futures market, price is determined in a competitive manner on the floor of exchange, and this price is transmitted all throughout the world through trading houses. If the price in the spot market is different from that in the futures market, equilibrium can be restored through arbitrage and reverse arbitrage. Thus, futures price leads to spatial integration of spot markets, which in turn will prevent local monopolies.

phenomenon has not been properly studied in any great detail. The received literature is deficient on a number of counts. Thus, many studies use data for the period immediately after the establishment of the national exchanges when the markets were not well established (Thomas and Karande 2001, Kumar 2004, Iyer and Pillai 2010, Mahalik et al. 2010, and Shihabudheen and Padhi 2010), and/or when the markets were very narrow in terms of crop coverage (Karande 2006, and Nath and Lingareddy 2008). In addition, some studies use agricultural price indices, so that their empirical results do not necessarily hold for the individual commodity prices underlying the indices (Mahalik et al. 2010, Srinivasan 2012, and Bhanumurthy, Dua and Kumawat 2013). Furthermore, some studies did not use deflated and de-seasonalized data (Shihabudheen and Padhi 2010, and Sehgal et al. 2014).

Our study attempts to deal with these shortcomings in a number of ways. It employs more recent, daily data, for the period May 2009 to August 2014. We focus on nine major agricultural crops – namely, wheat, barley, maize, gram, mustard, castorseed, soybean, coriander and cumin – simply because data on other agricultural crops of interest were not available. Furthermore, we use individual agricultural commodity price data rather than aggregate indices, where the data are appropriately deflated and de-seasonalized. Methodologically, we improve upon the received literature by testing for the presence of non-linear dynamic relationships between the spot and futures markets; when the underlying relationships are non-linear, presuming linear relationship might lead to inconsistent parameter estimates. Using data listed on the National Commodity and Derivative Exchange (NCDEX) and the Multi-Commodity Exchange (MCX), we find that the results provide strong evidence of nonlinear causality from futures prices to spot prices, but none in the reverse direction, for our sample commodities. We also find that there is a long term relationship amongst the agricultural commodity futures prices, but no short term causal relationship among them.

The paper is organized as follows. Section 2 describes the development of the model to be estimated, and provides its theoretical underpinnings. Section 3 discusses the data set. Section 4 discusses the estimation results and their interpretation. Finally, Section 6 provides the important conclusions and policy implications.

2. Developing the Estimation Model

The futures price of a commodity is related to its spot price via its 'carrying cost', i.e. the cost associated with carrying the commodity for a specified period, such as storage cost and handling cost. This may be expressed as:

$$FP_{t,T} = (1 + r_T)SP_t + k_T \quad (1)$$

where $FP_{t,T}$ is the futures price of the commodity at time t for delivery at time T, SP_t is the spot price at t , k_T is the carrying cost, and r_T is the risk-free interest rate for the period in question (Edward and Ma 2003). Defining the excess of the right hand side over the left hand side of equation (1) as an implicit 'convenience yield' (from holding on to the physical commodity) $\gamma_{t,T}$, we may re-write equation (1) as:

$$FP_{t,T} = (1 + r_T)SP_t + k_T - \gamma_{t,T} \quad (2)$$

Asset pricing theory tells us (Pindyck 2001), that if at time t a farmer buys one unit of a commodity at price SP_t, which he plans to hold until $t + T$ and sell it for SP_{t+T}, the expected return on his investment would be $E_t(SP_{t+T}) - SP_t + \gamma_{t,T} - k_T$. Since SP_{t+T} is unknown at t, the farmer's expected return is risky, and must be equal to the risk-adjusted discount rate times the spot price of the commodity at t, that is:

$$E_t(SP_{t+T}) - SP_t + \gamma_{t,T} - k_T = \rho_t SP_t \quad (3)$$

where ρ_t is the risk adjusted discount rate.

Combining (2) and (3) we get

$$FP_{t,T} = E_t(SP_{t+T}) - (\rho_T - r_T)SP_t \tag{4}$$

Equation (4) says that the futures price will equal the expected future spot price when the risk-adjusted discount rate is equal to the risk-free interest rate, that is, when there is no risk premium.

Although equations (1) and (4) describe the relationships between the futures price, spot price, and expected spot price, they are deficient on two counts and not suitable for estimation as they stand. First, the theory does not provide any insights about the lead-lag relationship between the spot and futures markets. Second, the above structure does not do justice to the essentially dynamic nature of the relationships in question. We now consider each of these criticisms in turn.

A priori it is possible for the relationship between the futures market and spot market to be bi-directional. The reason for the hypothesis that causality runs from futures prices to spot prices is that the futures market reflects new information more swiftly than the spot market due to lower transactions costs and greater flexibility. For example, suppose a supply shock indicates that agricultural commodity prices are expected to soar. We know that hedgers and speculators can execute futures contracts immediately with a small amount of cash, whereas spot buying requires greater financial resources and time since it involves visiting the market, enquiring about price and quality, and arranging transport and storage. Further, speculators are interested in futures contracts rather than spot contracts, because they are interested in earning profit from market price variations of the commodity rather than holding the commodity itself. Furthermore, future contracts are more liquid, since it is more problematic to get rid of the physical commodity. As a result, both hedgers and speculators will respond to the bad or good news by operating in the futures markets instead of spot markets. For all these reasons, spot markets respond to new information with a lag (Silvapulle and Moosa 1999). When new information leads to anticipated changes in agricultural commodity prices, hedgers and speculators respond by varying their demand for futures contracts, which is reflected in imbalance in the cost-of-carry equation. As arbitrageurs take action in spot and futures markets, that results in a change in the spot price till equilibrium is restored, which is reflected in the cost-of-carry equation holding again.

However, there could be reasons why the causality may run in the reverse direction, from spot prices to futures prices. This may happen if there are market participants who are either reluctant or not competent to trade in the futures market. These agents prefer to deal in the spot market. The resultant change in the spot price then triggers changes in the futures price via the response of arbitrageurs and speculators who modify their expectations about the spot and futures prices (Moosa 1996). Nevertheless, the case for causality running from the futures to the spot market appears to be stronger.

Moving now to the second deficiency mentioned above, attempts at hypothesizing an explicitly dynamic structure of the relationship between the spot and futures markets acknowledge that spot prices are influenced by their past history, current and past futures prices, and other market information. Likewise, futures prices are affected by their past history, current and past spot prices and other market information (Garbede and Silver 1983; Kawaller, Koch and Koch 1987; Moosa 2002).

2.1 Linear Granger causality model

A structural model such as equations (1) and (4) above is not only deficient in the ways pointed out above, but is also difficult to estimate since it involves unobservable variables such as expectations. A more practical way of specifying an empirical model that allows us to study the lead-lag relationship between futures and spot prices and also takes care of both the above-mentioned points is via the linear Granger causality model, which may be stated as follows:

$$dlnSP_{ct} = \alpha_1 dlnFP_{c(t-1)} + \cdots + \alpha_k\, dlnFP_{c(t-k)} + \beta_1 dlnSP_{c(t-1)} + \cdots + \beta_k\, dlnSP_{c(t-k)} + u_{ct} \tag{5a}$$

$$dlnFP_{ct} = \gamma_1\, dlnSP_{c(t-1)} + \cdots + \gamma_m\, dlnSP_{c(t-k)} + \delta_1\, dlnFP_{c(t-1)} + \cdots + \delta_m\, dlnFP_{c(t-k)} + v_{ct} \tag{5b}$$

where subscript c refers to the commodity in question, and all other variables have been defined above.

However, the linear Granger causality testing procedure has been shown to have low power vis-à-vis causal relationships that are inherently non-linear (Hiemstra and Jones 1994). Further, an incorrect specification may lead to inconsistent parameter estimated. We, therefore, prefer a nonlinear specification to model the relationship between spot and futures prices.

2.2 Non-linear Granger causality model

"Nonlinear models represent the correct way to model a real world that is almost certainly nonlinear", advises Granger (1989). Dynamic relations between spot and futures markets are likely to be non-linear due to the great heterogeneity of market participants. Participants in agricultural spot markets are farmers and consumers, whereas those in agricultural futures markets are speculators, hedge funds, mutual funds, and swap dealers. These agents have very different objectives. Farmers and consumers have more interest in the physical commodity and operate in the spot markets, although they also hedge their position in the futures markets. In contrast, speculators, hedge fund managers, and swap dealers are more interested in profiteering from fluctuations in agricultural prices, and operate in the futures markets.

Further, the different agents have different investment horizons as well. Since farmers take cultivation decisions without necessarily knowing the subsequent market price, they take a longer term view on crop prices than do consumers. Speculators with very short time horizons (or 'market makers' as they are called), are not concerned about bull or bear markets, for their sole objective is to purchase futures contracts at a given price and sell them at even a marginally higher price. Speculators with longer time horizons (or 'day traders' and 'trend followers' as they are called), operate in the market for longer periods of time (Bahattin and Harris 2012). In addition to these rational agents are the 'noise traders', who tend to base their decision-making on 'noise'[3] rather than solid economic evidence (Black 1986).

In addition to the above-mentioned complexities of the spot and futures markets, we hypothesize the appropriateness of a non-linear model in our context partly on the basis of the nature of our data, and partly on the basis of statistical tests. The nature of our data in both markets has already been explained in the previous section, and need not be repeated here. Focusing on the statistical tests instead, we feel that pretesting for nonlinearity protects us from over-fitting the data. The test statistics for both the Ramsey

[3] Noise differs from information, and refers to hype, wrong ideas and imprecise data. Noise traders generally have poor timing, are trend followers, and over-react to good and bad news.

Regression Equation Specification Error Test or RESET test as well as the Squared Residual test, indicate the presence of non-linearity in the relationship between the spot and futures markets for all sample crops (Table 5). Thus, we find that the divergent objectives and differing time horizons of the agents involved in these markets likely make for complex, nonlinear relationships.

A tractable nonlinear characterisation of the relationship between futures and spot prices may be expressed as:

$$dlnSP_{ct} = f[dlnFP_{c(t-1)}, \dots, dlnFP_{c(t-k)}] + \beta_1 dlnSP_{c(t-1)} + \cdots + \beta_k dlnSP_{c(t-k)} + u_{ct} \qquad (6a)$$

$$dlnFP_{ct} = f[dlnSP_{c(t-1)}, \dots, dlnSP_{c(t-k)}] + \delta_1 dlnFP_{c(t-1)} + \cdots + \delta_m dlnFP_{c(t-k)} + v_{ct} \qquad (6b)$$

where both relationships comprise a nonlinear component and a linear component. As a first approximation, we allow only the futures price-spot price relationship to be nonlinear, so as to conserve scarce degrees of freedom, since our sample size is just not large enough. To avoid having to make unnecessary assumptions about the functional form of the nonlinear component, we estimate it using semi-parametric regression techniques.

3. The Data Set

In this study we use futures and spot price data for wheat (W), maize (MZ), barley (B), mustard (MS), gram (G), soybean (SB), castorseed (CS), coriander (CD) and cumin (C). Our choice of commodities was determined both by their importance as well by the simple fact of data availability. We realise that there are many other commodities of significance in Indian agriculture, but data were not available for them. The futures and spot price data were collected from the websites of the National Commodity and Derivative Exchange

(NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai. Alternative futures contracts are traded simultaneously on a daily basis. Of these, we chose the so-called 'nearby contract'[4] for our analysis, because it is the most liquid contract of all (Crain and Lee 1996). All data are available on a daily basis for six days a week (barring Sunday, and national holidays[5]), from May 2009 through August 2014. However, due to trading breaks for crops the number of observations varies by crop – being 1476 for wheat, 1286 for maize, 1266 for barley, 1450 for mustard, 1342 for gram, 1460 for soybean, 1325 for castorseed, 1277 for coriander, and 1269 for cumin.

Table 1 presents the descriptive statistics of the daily spot and futures returns for the sample commodities. The mean returns are positive for all except wheat spot, cumin spot and cumin futures. Measuring volatility by standard deviation, we find that it is highest for coriander futures (2.0) followed by castorseed futures (1.6) and coriander spot (1.5). The lowest volatility is seen in cumin spot returns (0.5) and wheat spot returns (0.6). The futures market has greater volatility vis-à-vis the spot market for almost all crops. The Jarque-Bera test statistics signify that the returns distribution is not normal for most commodities, except the futures returns of coriander, gram and cumin, and the spot returns of gram and cumin.

3.1 Preparing the data for estimation

We start off by removing the components of inflation and trend from the spot and futures prices of each of our sample commodities. The prices are made inter-temporally comparable by deflating them by the crop-specific wholesale price indices provided by the

[4] The nearby contract is the futures contract whose delivery should be at least one month away.

[5] There are three national holidays in India – Independence day (August 15), Republic day (January 26), and Mahatma Gandhi's birthday (October 5).

Office of the Economic Advisor, Government of India. We next test for trend in the deflated prices, first employing the Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, and then the Dickey–Fuller generalized least squares (DF-GLS) test proposed by Elliot et al. (1996) for detecting a unit root in the series. The DF-GLS test is a second generation test, and has greater power than the first generation DF, ADF and PP tests. Including a deterministic trend and intercept as per the data plots, and determining the optimum lag length using the Schwarz Criterion, the DF-GLS test revealed that the spot and futures prices of all crops are nonstationary in levels, so that we opt to work with the log (first) differences of the prices (Table 2). We then use seasonal dummies to remove the seasonal effect. Finally, using the Elliot-Muller test (Elliot and Muller 2006), we do not find any structural break in the spot and futures returns for our sample commodities, except for the gram spot price. However, since the latter is not found to correspond to any discontinuous spot price change, we ignore it in our further analysis.

4. Estimation Results

To study the lead-lag relationship between the spot and futures markets, we start off by removing the impact of inflation, trend and seasonality from the spot and futures prices of each of our sample commodities. We then employ linear Granger causality test to examine the lead-lag relationship between spot and futures returns.

4.1 Linear Granger causality results

The linear Granger causality model examines whether past values of one variable can help explain current values of a second variable, conditional on past values of the second variable. Intuitively, it determines whether past values of the first variable contain additional information on the current value of the second variable that is not contained in past values of the latter. If so, the first variable is said to Granger-cause the second variable.

Tables 3 and 4 present the linear Granger causality model results for spot and futures returns for all nine commodities. While Table 3 reports the F-statistic for the null hypothesis that futures returns do not Granger cause spot returns, Table 4 reports F-statistics for the 'reverse' null hypothesis that spot returns do not Granger cause futures returns. For the Granger causality models, the optimum lag lengths were selected using the Akaike Information Criterion (AIC), the Schwarz Criterion (SC), the Hanan-Quinn Criterion (HQ), the Final Prediction Error (FPE), and the likelihood ratio (LR) test statistic criterion. As can be seen from Table 3, the null hypothesis that the returns in futures markets does not Granger-cause the returns in spot markets is very strongly rejected in the case of all crops, the associated F-statistics turning out to be large and significant, with p-value of 0 or close to 0.

However, the 'reverse' null hypothesis that returns in spot markets do not Granger cause returns in futures markets (Table 4) is not rejected for all crops. We, therefore, conclude that there is unidirectional causality running from futures returns to spot returns for all of our sample crops. This finding is consistent with previous findings of Garbade and Silber (1983), Moosa (2002), Sehgal *et al*. (2014) and Shihabudheen and Padhi (2010), and suggest that futures markets dominate spot markets for the commodities studied or, equivalently, that the spot price is discovered in the futures market. The information flow from futures to spot markets also appears to have intensified in the past years, because the causal relationship is remarkably stronger in our study as compared to previous studies like Shihabudheen and Padhi (2010) and Mahalik, Acharya and Babu (2009). The causal relationship is stronger because the associated F-statistic is large with p-value of 0 or close to 0, for all crops. This obvious increase in information flows may possibly be due to growing relative significance of commodity futures' electronic trading vis-à-vis open auction in *mandis* (or auction markets) during the past years. Commodity futures' electronic trading results in transparent and competitive price, and this price is transmitted all throughout the world through trading houses.

4.2 Nonlinear Granger causality results

Before presenting and discussing the results of the nonlinear model, it would be useful to discuss the results of pre-testing the underlying data. Pretesting for nonlinearity protects us from over-fitting the data. The results of the Ramsey Regression Equation Specification Error Test (RESET) as well the Ljung-Box squared residual test in Table 5, both indicate the presence of nonlinearity in the price data.

Theory does not suggest a particular functional form for modeling the relationship between spot and futures markets. We have, therefore, used the partial linear or nonlinear model to obtain consistent estimates of the parameters of interest. This has been done to conserve degree of freedom, as explained in section 2.2 above, since our dataset is not large enough. Tables 6 and 7 present the partial linear or 'nonlinear' Granger causality test results for the sample commodities. Table 6 reports the t-statistic for the null hypothesis that futures returns do not Granger-cause spot returns; while Table 7 reports the t-statistic for the 'reverse' null hypothesis that spot returns do not Granger cause futures returns. We find that for all crops except maize, the former null hypothesis is rejected, implying that even after removing the linear dependence, futures returns partially Granger cause spot returns for wheat, barley, gram, mustard, castorseed, soybean, coriander and cumin. Further, Table 7 shows that spot returns do not partially Granger cause futures returns for all crops. Thus, the basic finding of this study is that the futures market performs the role of price discovery, implying that the spot price moves towards the futures price when the two deviate in the short run. This is consistent with previous findings of (Silvapulle and Moosa 1999), and Harnandez and Torero (2010).

5. Conclusions and Policy Implications

This study estimates linear and partial linear Granger causality models to examine the lead–lag relationship between spot and futures prices. The evidence provided by linear Granger causality results suggests that futures markets dominate the spot markets for all crops, so that price changes in futures markets lead price changes in spot markets for these crops. Further, partial linear causality tests provide no evidence of nonlinear causality from spot prices to futures prices for the sample crops. If there is any strong nonlinear causal relationship, it is from futures to spot markets for wheat, barley, gram, mustard, castorseed, soybean, coriander and cumin. Price discovery occurs in the futures markets because the futures market reflects new information more quickly than the spot market due to lower transaction costs and greater flexibility. Our results lead us to opine, that provision of information on futures price to Indian agriculturists on a daily basis would make for greater efficiency in their decision-making. Further, it would allow them to use the futures price information to maximise profits, by deciding whether to hold on to their output or sell at any given point in time.

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Table 1: Descriptive statistics of daily returns in some primary commodity spot and futures markets

	Mean	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	*Jarque-Bera statistic*	Observations
Barley SP	0.016	1.794	-1.788	0.625	-0.070	30356	7.752**	1265
Barley FP	0.004	2.932	-2.958	1.092	0.202	3.219	11.209***	1265
Castorseed SP	0.014	4.445	-4.312	1.214	-0.106	5.448	333.545***	1325
Castorseed FP	0.012	5.448	-5.598	1.576	-0.093	4.020	59.404***	1325
Coriander SP	0.002	5.815	-5.969	1.510	-0.237	5.134	254.374***	1277
Coriander FP	0.015	6.887	-6.172	2.012	0.095	3.185	3.774	1277
Gram SP	0.043	2.990	-2.982	1.091	0.007	3.062	0.226	1342
Gram FP	0.035	2.995	-2.989	1.126	0.091	2.869	2.812	1342
Maize SP	0.010	2.191	-2.299	0.647	-0.111	4.635	145.964***	1286
Maize FP	0.005	3.468	-3.251	1.040	0.277	3.889	58.923***	1286
Mustard SP	0.017	8.615	-8.119	1.020	-0.421	18.516	14588.04***	1450
Mustard FP	0.040	3.995	-3.367	0.998	0.114	3.917	54.003***	1450
Soybean SP	0.053	3.464	-3.858	1.043	-0.177	4.182	92.664***	1460
Soybean FP	0.054	5.973	-5.632	1.370	-0.043	4.224	91.615***	1460
Wheat SP	-0.006	2.246	-2.294	0.566	-0.134	5.987	553.359***	1476
Wheat FP	0.018	3.774	-4.487	0.831	-0.166	6.884	934.757***	1476
Cumin SP	-0.016	1.387	-1.349	0.503	0.109	3.089	1.941	1269
Cumin FP	-0.049	2.959	-2.988	1.186	-0.023	2.747	3.489	1269

Notes: FP – futures price; SP – spot price.
***, **, and * indicate significance at the 1%, 5% and 10% levels

Table 2: DF-GLS Unit Root test

Variable	Levels (T&I)	First difference	Inference at 5%
Barley SP	-2.188	-35.731***	I(1)
Barley FP	-0.581	-8.213***	I(1)
Castorseed SP	-1.125	-9.295***	I(1)
Castorseed FP	-1.449	-34.824***	I(1)
Coriander SP	-1.028	-33.475***	I(1)
Coriander FP	-1.174	-33.077***	I(1)
Gram SP	-1.104	-33.417***	I(1)
Gram FP	-1.326	-35.826***	I(1)
Maize SP	-2.748	-9.945***	I(1)
Maize FP	-2.551	-3.948***	I(1)
Mustard SP	-1.692	-33.743***	I(1)
Mustard FP	-2.099	-3.877***	I(1)
Soybean SP	-1.335	-3.484***	I(1)
Soybean FP	-1.441	-3.194**	I(1)
Wheat SP	-2.004	-6.722***	I(1)
Wheat FP	-2.288	-13.402***	I(1)
Cumin SP	-1.530	-2.972**	I(1)
Cumin FP	-1.914	-3.806***	I(1)

Notes: FP – futures price; SP – spot price.
***, **, * denotes significance at 1%, 5%, 10% level implying that the null of unit root is rejected
T&I stand for trend and intercept
I(1) stands for integrated of order one.

Table 3: Granger Causality linear test of daily returns in spot and futures markets

Null Hypothesis			Lags	F-statistic	Conclusion
Barley FP	does not Granger cause	Barley SP	2	23.081 ***	Reject H_0
Castorseed FP	does not Granger cause	Castorseed SP	3	48.731 ***	Reject H_0
Coriander FP	does not Granger cause	Coriander SP	4	27.344 ***	Reject H_0
Gram FP	does not Granger cause	Gram SP	3	77.674 ***	Reject H_0
Maize FP	does not Granger cause	Maize SP	3	8.949 ***	Reject H_0
Mustard FP	does not Granger cause	Mustard SP	2	112.070 ***	Reject H_0
Soybean FP	does not Granger cause	Soybean SP	1	117.176 ***	Reject H_0
Wheat FP	does not Granger cause	Wheat SP	1	8.534 ***	Reject H_0
Cumin FP	does not Granger cause	Cumin SP	1	123.185 ***	Reject H_0

Notes: FP – futures price; SP – spot price.
***, **, and * indicate significance at the 1%, 5% and 10% levels
Lags selected according to Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), Hanan-Quinn Information Criterion (HQ), final prediction error (FPE) and LR test statistic criterion.

Table 4: Granger Causality linear test of daily returns in spot and futures markets

Null Hypothesis			Lags	F-statistic	Conclusion
Barley SP	does not Granger cause	Barley FP	2	1.031	Do not reject H_0
Castorseed SP	does not Granger cause	Castorseed FP	3	1.119	Do not reject H_0
Coriander SP	does not Granger cause	Coriander FP	4	0.916	Do not reject H_0
Gram SP	does not Granger cause	Gram FP	3	1.736	Do not reject H_0
Maize SP	does not Granger cause	Maize FP	3	1.968	Do not reject H_0
Mustard SP	does not Granger cause	Mustard FP	2	0.807	Do not reject H_0
Soybean SP	does not Granger cause	Soybean FP	1	1.546	Do not reject H_0
Wheat SP	does not Granger cause	Wheat FP	1	0.380	Do not reject H_0
Cumin SP	does not Granger cause	Cumin FP	1	0.354	Do not reject H_0

Notes: FP – futures price; SP – spot price.
***, **, and * indicate significance at the 1%, 5% and 10% levels
Lags selected according to Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), Hanan-Quinn Information Criterion (HQ), final prediction error (FPE) and LR test statistic criterion.

Table 5: Ramsey RESET test and Ljung-Box squared residual test

Crops	Ramsey Test F-statistic	Ljung-Box test F-statistic
Barley	2.789 **	148.910 ***
Castorseed	8.184 ***	52.034 ***
Coriander	2.620 **	40.634 ***
Gram	7.104 ***	88.871 ***
Maize	3.623 **	59.792 ***
Mustard	3.474 **	259.650 ***
Soybean	6.315 ***	71.714 ***
Wheat	2.409 **	119.210 ***
Cumin	3.404 **	49.225 ***

Notes: RESET – Regression Equation Specification Error Test
***, **, and * indicate significance at the 1%, 5% and 10% levels

Table 6: Nonlinear Granger causality test of daily returns in spot and futures markets

Null Hypothesis			Lags	T-ratio	Conclusion
Barley FP	does not Granger cause	Barley SP	1	1.497 *	Reject H_0
Castorseed FP	does not Granger cause	Castorseed SP	1	3.806 ***	Reject H_0
Coriander FP	does not Granger cause	Coriander SP	1	3.125 ***	Reject H_0
Gram FP	does not Granger cause	Gram SP	1	7.387 ***	Reject H_0
Maize FP	does not Granger cause	Maize SP	1	0.970	Do not reject H_0
Mustard FP	does not Granger cause	Mustard SP	1	4.276 ***	Reject H_0
Soybean FP	does not Granger cause	Soybean SP	1	3.750 ***	Reject H_0
Wheat FP	does not Granger cause	Wheat SP	1	1.968 **	Reject H_0
Cumin FP	does not Granger cause	Cumin SP	1	3.815 ***	Reject H_0

Notes: ***, **, and * indicate significance at the 1%, 5% and 10% levels
Yatchev's (1997) T-ratios reported

Table 7: Nonlinear Granger causality test of daily returns in spot and futures markets

Null Hypothesis			Lags	T-ratio	Conclusion
Barley SP	does not Granger cause	Barley FP	1	-0.161	Do not reject H_0
Castorseed SP	does not Granger cause	Castorseed FP	1	0.082	Do not reject H_0
Coriander SP	does not Granger cause	Coriander FP	1	-0.046	Do not reject H_0
Gram SP	does not Granger cause	Gram FP	1	0.743	Do not reject H_0
Maize SP	does not Granger cause	Maize FP	1	0.110	Do not reject H_0
Mustard SP	does not Granger cause	Mustard FP	1	-1.945	Do not reject H_0
Soybean SP	does not Granger cause	Soybean FP	1	-0.823	Do not reject H_0
Wheat SP	does not Granger cause	Wheat FP	1	0.413	Do not reject H_0
Cumin SP	does not Granger cause	Cumin FP	1	0.523	Do not reject H_0

Notes: ***, **, and * indicate significance at the 1%, 5% and 10% levels
Yatchev's (1997) T-ratios reported