Price discovery in some agricultural commodity markets in India

Work in Progress

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Abstract

Since 1991, a number of wide-ranging economic reforms have been undertaken in India. In the changing environment, various agents have been exposed to increased price risk in commodity markets. Futures markets are one important instrument for reducing price risk. In this study we focus on the price discovery role of futures markets. In the Indian context, a detailed examination of the available Indian data on the direction of causality between futures and spot agricultural commodity markets does not disclose any unambiguous direction of impact. Hence, there is a need to examine the lead-lag relationship between spot and futures markets anew. This study also examines the interdependence of futures prices of various crops traded on the national commodity exchanges.

In this study we use daily futures and spot price data for thirteen crops from August 2009 to September 2014. We employ partial linear *(*semiparametric) Granger causality tests to explain the nonlinear causal relationship*.* The results provide strong nonlinear causal relationship from futures to spot markets*.* These results lead us to opine, that the authorities need inform futures price to farmers on daily basis so that farmers can decide about its storage and cropping pattern depending on the price signals from futures market.

Key words: Agricultural price policy, Futures market, Commodity market, Food Security

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1. Introduction

Since 1991, a number wide-ranging economic reforms resulting in increasing liberalisation of markets and removal of state intervention, have been undertaken in India. 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.

There are two important social benefits of futures markets: (i) price discovery; and (ii) risk management through hedging. In this study we focus on the price discovery role of futures markets. Price discovery[2] is the ability of the market to discover true 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).

In the Indian context, commodity futures trading started in 2003. Over a period of eleven years, Indian commodity futures grew at a very high rate, but despite that the role of futures markets has been met with much scepticism and a lot of questions have been raised regarding its benefits. A detailed examination of the available Indian data on the direction of causality between futures and spot agricultural commodity markets does not disclose any unambiguous direction of impact. (Government of India 2008; Bhanumurthy, Dua and Kumawat 2013). Hence, there is a need to examine the causal relationship between spot and futures markets anew.

Futures prices denote fairly observed price expectations at a future date. These prices are the end result of open and competitive trading on the floor of the exchange, and per se reveal the underlying supply and demand for a commodity, both in the present and the future. If a farmer 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 investment accordingly (Government of India 2008). In addition, as the harvest time nears,

[2] The term price discovery is explained in detail in appendix D.

knowledge of the price likely to exist much after harvest can help him to decide whether to sell or retain his crop at harvest time. Consequently, given his capability and access to other enabling infrastructure such as warehousing, finance etc., he will be able to exert his marketing option in such a way as to maximize his income realization.

If causality is from the futures to the spot market, this transmission of informational anchor can serve both producers and consumers by reducing local monopolies and allowing better inventory management. Also, there can be stronger spatial integration between spot markets, preventing local monopolies and promoting greater efficiency and welfare. The futures market can serve as the reference for the spot market.

One of the reasons for opening up and reviving 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 view of the above discussion, the phenomenon of the lead–lag relationship between spot and futures agricultural commodity prices has been of great consequence.[3] In this wider context, the present study examines the issue of "Whether the changes in futures prices lead to changes in spot prices, or whether price changes in spot markets lead to price changes in futures markets, or whether the information flows between the spot and futures markets are bidirectional."

[3] If futures price leads spot price, farmers will benefit. If spot price leads futures price, farmers won't benefit from this transmission. It shows inefficient futures market where volume of transactions is low or futures market is at infancy stage. If there is a bidirectional information flow between spot and futures market, it shows both markets are efficient. Bidirectional information flows between spot and futures market signifies highly developed agricultural commodity markets.

This study also examines the interdependence of futures prices of various crops traded on the national commodity exchanges. A finding of significant linkages[4] between the agricultural commodities, would imply the existence of cross speculation and cross hedging opportunities, and would justify the introduction of futures contracts for new crops.

A quick literature survey reveals that even the relatively recent studies in this area in the Indian context are methodologically unsatisfactory (Sehgal, Ahmad and Deisting 2014; Shihabudheen and Padhi 2010). The existing empirical evidence is consistently based on the usual (linear) Granger causality testing, which has been shown to have low power in explaining nonlinear causal relationship (Hiemstra and Jones 1994). More recent work, however, has revealed the existence of nonlinear dynamic relations between spot and futures agricultural commodity prices (Harnandez and Torero 2010). Non-linear relationship between spot and futures markets are due to non-linear transaction and storage costs, noisy traders and varying market microstructures.

The present paper addresses this limitation by employing more recent futures and spot price data for some agricultural crops – namely, wheat, barley, maize, gram, mustard, castorseed, soyabean, zeera, chilli, coriander, pepper, zeera and cotton seed oilcake. These are some of the important commodities for the Indian economy, as well as those for which data are available. We took the futures and spot price data for these commodities from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai. All data are available on a daily basis, i.e. six days a week, from August 2009 to September 2014. The presence of nonlinear causation is studied. The results provide no evidence of nonlinear causality from changes in spot prices to changes in futures prices. If there is any strong nonlinear causal relationship, it is from futures to spot markets, for our sample commodities. The results also show that there is a long term relationship

[4] A finding of significant linkages between the agricultural commodities, would also imply that the price discovery in the futures market of one commodity will provide valuable information to other commodity markets.

amongst the agricultural commodity futures prices. However, we could not observe any short term causal relationship even among the related agricultural commodities.

The paper is organized as follows. Section 2 describes the theoretical considerations and empirical evidence. Section 3 discusses the model used in the present study, and the estimation methodology adopted. Section 4 presents a description of the data used. Section 5 presents the estimation results; and, finally, Section 6 provides the important conclusions and policy implications.

2. Theoretical considerations and existing literature

The futures price and spot price of a commodity are related by the cost of carry relationship. The cost of carry determines the extent to which the futures price of a commodity exceeds the spot price of that commodity. The 'cost of carry' refers to the costs associated with purchasing and carrying a commodity for a specified period of time. Thus, we have[5] (Edward and Ma 2003, p. 91).

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

where $FP_{t,T}$ is the futures price of agricultural commodity at time t for delivery at T, SP_t is the spot price at t , k_t is the storage cost, r_T is the (risk free) interest rate for period T.

[5] Cost of carry equation is same as non-arbitrage equation. Full carry price is another name for arbitrage price.

If we see a relationship where the actual futures price $(FP_{t,T})$ is less than $(1+r_T)SP_t + k_t$, we say that $FP_{t,T}$ contains an implicit convenience yield[6] γ_t. In this case we must rewrite the above formula as:

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

$$\Rightarrow (1+r_T)SP_t + k_t - FP_{t,T} = \gamma_t \quad (3)$$

$$\Rightarrow FP_{t,T} - FP_{t,T} = \gamma_t \quad (4)$$

From asset pricing theory (Pindyck 2001), we can also find a relationship between the futures price and expected future spot price. Assume that at time t, a farmer buys one unit of a commodity at price SP_t, which he plans to hold until $t+T$ and then sell it for SP_{t+T}. The expected return of this investment is given by $E_t(SP_{t+T}) - SP_t + \gamma_{t,T} - K_T$. Since SP_{t+T} is unknown at t, this return is risky and must be equal to the risk adjusted discount rate times the price of the commodity at t.

$$E_t(P_{t+T}) - P_t + \gamma_{t,T} - K_T = \rho_t P_t \quad (5)$$

where ρ_t is the risk adjusted discount rate.

Substituting (4) into (5), we find

$$F_{t,T} = E_t(P_{t+T}) - (\rho_T - r_T)P_t \quad (6)$$

From equation (6), the futures price will equal the expected future spot price if the risk adjusted discount rate is equal to the risk free rate (i.e., when there is no risk premium).

Equations (1) and (6) show the explicit relationships between the spot, futures and expected spot prices. However, the theory does not provide any insights about the lead-lag relationship between the spot and futures markets. Identifying the causal

[6] Whenever there is shortage of physical commodity, its holders do not want to part with it, even for a short period of time. When this occurs we say that the commodity possesses a convenience yield: there is an implied yield (return) from simply holding the commodity. This yield may not be directly measurable. It could be for example, be the implicit return that a firm places on its ability to use its inventory to supply without interruption its longstanding customers – its customer goodwill. A key difference between commodity futures and financial futures is that commodity futures are often subject to the existence of a convenience yield.

relationship between spot and futures agricultural commodity prices, then, appears to be an empirical issue.

Whenever there is consistent rise in inflation rate, people criticise the futures market for price fluctuations in the agricultural spot market. People believe that the causal relation is from futures to spot market, not vice versa. After the 2007-8 financial crisis government of India stopped futures trading in wheat, rice, urad and tur; and set up a committee to look at the role of futures market in the price rise of agricultural commodity (Government of India 2008). The key reason for this hypothesis that futures prices lead spot prices is that the futures market reflects new information more swiftly than the spot market due to lower transaction costs and greater flexibility. We will illustrate this point by taking the example of agricultural commodity markets. If some bad news indicates that agricultural commodity prices are expected to soar, a speculator has the option of either purchasing agricultural commodity futures or spot. One can execute futures contracts immediately with small amount of cash (because of margin trading) whereas spot buying needs more money and may take a longer time to execute[7] the transaction.

It is also be argued that, speculators are interested in holding futures contract rather than physical commodity because they are interested in earning profit from variations in the market value of a agricultural crop. Also, the future markets have greater liquidity. Additionally, hedgers who require the physical commodity, but do not have storage capacity, will hedge themselves by purchasing futures contracts. 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. Since we cannot perform spot transactions so swiftly, spot markets respond to new information with a lag.

The second reason for the hypothesis that the causal relation runs from futures markets to spot markets is that futures markets serve the function of price discovery (Edward and Ma 2003, p.164). Price discovery implies that futures price is a good forecaster of spot price which takes into consideration storage costs, transportation costs… etc

[7] They have to go to market, enquire about price and quality, arrange for transport and warehouses.

The available empirical evidence on the lead-lag relationship is mixed.

Garbede and Silber (1983) examined the phenomenon of price discovery in seven storable commodities: namely, wheat, corn, oats, orange juice, gold, copper and silver. They found that the futures market dominated the spot market in the price discovery role. However, the spot market also played a role in price discovery. The role of the spot market in price discovery suggests that there is a flow of information from spot to futures market. Further, the authors also found that price discovery role of spot market in these seven commodities was a result of the market size and liquidity.

Quan (1992) analysed causal relation between spot and futures crude oil market by taking monthly data and found that the causal relation is from spot market to futures market. Schwarz and Szakmary (1994) had reservations about Quan's conclusion. They enquired why futures markets would exist if they did not perform 'one of the basic functions', that is, price discovery. Their empirical findings, using high frequency data, imply that the causal relation is from futures markets to spot markets. These authors ascribe Quan's failure to find support for the price discovery function of the futures market to the frequency of the (monthly) data used by Quan.[8]

Futures trading can also facilitate the allocation of production and consumption over time, particularly by providing market guidance in the holding of inventories (Edward and Ma 2003, p.166).

There is a possibility that futures markets will offer chances for market manipulation (Newberry 1992). This means that either the better informed player without regard for less informed or the larger player at the cost of smaller, can influence futures market. Futures price affects the production decisions of the producers. We are considering the special case of pure demand risk, implying there is no output uncertainty in the economy. In this situation, future price will determine the production decisions of the producers. Big producers for instance, Brazil for coffee, may therefore, consider it lucrative to interfere in futures markets to affect the spot market production decisions of their rivals. In the extreme case, large producers may consider it profitable to

[8] Data should be either high frequency or daily.

increase price volatility in futures market. However, the degree to which this is viable will be restricted by number of other speculators and, also by other speculators' risk forbearance (Newberry 1984). The above arguments will hold even under the assumption of rational expectations, and all agents have complete information (with the exception of the actions of big producers). This is another argument for the hypothesis that the futures markets lead the spot markets.

Moosa and Al-Loughani (1995) also support the hypothesis that the causal relation is from futures markets to spot markets. In their paper, the futures price is determined by (i) arbitrageurs whose demand for futures contracts is decided by the gap between the arbitrage price[9] (see equation (A) in section 2) and the actual futures price; and (ii) speculators whose demand is determined by the gap between the expected spot price and the actual futures price. Futures price, not the spot price is the reference point in both cases. When there is information indicating that agricultural commodity prices are anticipated to increase in the future, speculators will respond by varying their demand for futures contracts, and thereby, leading to the violation of the cost-of-carry condition. As a result, arbitrageurs will take action in spot and futures markets and will change the spot price. The arbitrageurs will remain active till a point the cost-of-carry equation is restored.

Now, we make arguments for the support of the hypothesis that spot prices lead futures price. There are participants who are either reluctant to or incompetent of trading in the futures market. These people deal only in spot market. As a result, the spot price changes due to change in demand of the physical commodity. This change in spot price triggers a series of events. The three kinds of market participants will respond to the change in the spot price that will then change the futures price (Moosa 1996). To begin with, arbitrageurs will respond to the violation of the cost-of-carry equation (see equation (A) in section 2). Second, speculators who take action on the expected spot price will modify their expectation and react to the gap between the futures price and the expected spot price. Similarly, speculators who make decisions on the expected futures price will amend their expectation and act in response to the

[9] Arbitrage price is same as cost of carry price.

gap between the current futures price and the expected futures price. In this case, spot prices lead futures prices.

Kawaller et al. (1988) say 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. Thus, causality is bidirectional. They also say that the lead and lag relations between futures and spot prices are likely to change as new information arrives. Either market can lead the other, as market participants filter the news for hints that are appropriate to their positions, which may be spot or futures. In fact, one can say that lags are not only present between movements in futures prices and consequent movements in the spot prices but also vice versa.

The inference that can be derived from the above argument is that there is some justification and empirical support for the hypothesis that futures prices lead spot prices, as well as for the hypothesis that spot prices lead futures prices. Nevertheless, the case for the first hypothesis is stronger and more convincing. Hence, further empirical testing is needed to make a decision, or at least to throw some light on, this issue as applied to the Indian agricultural commodity markets.

2.1 Linkages amongst agricultural commodity futures prices

The movement of the agricultural commodity prices are interdependent. There are several reasons to expect an interdependence between crop futures prices. Firstly, the agricultural commodity prices are linked through substitutability and complementarity. Substitution between the crops can happen in different way: they might be grown at same time, but still they can compete if they are grown in same area. Suppose farmers in Punjab are growing both wheat and gram. The substitution between areas can happen, so the prices of wheat will affect prices of gram and price of gram will affect prices of wheat. Substitutability and complementarity can occur in production as well as in consumption. For example wheat and gram are substitutes in production whereas wheat and rice are substitutes in consumption.

Complementarity in production means that the crops grown together. Complementary crops help in the growth of other crops by suppling nutrients and preventing from pests. For example, Pepper are intercropped with tomatoes, peas are grown together with turnips, cauliflower or garlic. Complementarity in consumption is related to the nutrients contents of the crop. While gram and soyabean are high in protein, wheat is high in carbohydrates. Wheat and gram can be used along with soyabean in various proportions. Agricultural commodities might be both complements and substitutes. For example, wheat and mustard are substitutes because they are grown in same area. However, wheat is rich in carbohydrate and mustard is rich in fat. We need both nutrients for our body. So, these two crops are substitutes and complements both. Thus, substitutability and complementarity are not strictly mutually exclusive in agricultural sector (Malliaris and Urrutia 1996).

Secondly, common macroeconomic factors such as aggregate demand, inflation, exchange rates and interest rates…etc, all affect agricultural commodity prices within (and across) economies. Third, speculative behaviour causes the co-movement of agricultural commodities, partly because imperfect capital markets [10] imposes liquidity constraints on speculators, and partly because herd behaviour in financial markets leads to commodity price co-movement (Pindyck and Rotemberg 1990).

.3. Model and methodology used in this study

To study the dynamic relationship between the spot and futures markets, we start off by testing for the stationarity of the spot and futures prices of each of our sample commodities. Since these were found to be nonstationary, we opted to work with the log (first) differences of the prices. We then consider the following linear model:

3.1 Linear Granger causality model

A. $$dlnSP_{ct} = \alpha_1 dlnFP_{c(t-1)} + \cdots + \alpha_k\, dlnFP_{c(t-k)} + \beta_1 dlnSP_{c(t-1)} + \cdots + \beta_m\, dlnSP_{c(t-m)} + \mu_{ct} \qquad (7)$$

B. $$dlnFP_{ct} = \gamma_1\, dlnFP_{c(t-1)} + \cdots + \gamma_k\, dlnFP_{c(t-k)} + \delta_1\, dlnSP_{c(t-1)} + \cdots + \delta_m\, dlnSP_{c(t-m)} + \vartheta_{ct} \qquad (8)$$

[10] There is limited amount of money with speculators.

where c = wheat (W), maize (MZ), barley (BL), mustard (MS), gram (G), sugar (S), soyabean (SB), castorseed (CS), coriander (CD), chilli (CH), pepper(PP), zeera (Z) and cotton seed oilcake(CO); SP is the spot price, FP is the futures price, and t denotes the time period, k and m are the number of lags in the model.

In equation (7), first difference of log of futures price does not Granger cause first difference of the log of spot price if the lags of first difference of log of futures price in this equation are all insignificant. If first difference of log of futures price causes first difference of the log of spot price, lags of first difference of log of futures price should be significant in the equation (7). If this is the case and not vice versa, one can say first difference of log of futures price Granger causes first difference of the log of spot price. There is the uni-directional causality from first difference of log of futures price to first difference of the log of spot price.

Subsequently, in equation (8) if first difference of the log of spot price Granger causes first difference of log of futures price, lags of first difference of the log of spot price should be significant in this equation. There would be bi-directional causality if the both sets of lags are significant.

First difference of the log of spot price and first difference of log of futures price are said to independent if neither sets of lags are significant in the equation for the other variables.

3.2 Partial[11] linear Granger causality test

Granger (1989) argues that nonlinear models represent the correct way to model a real world that is almost certainly nonlinear. Before presenting and discussing the nonlinear model that we employ in this paper, it is worthwhile to elaborate on the issue of nonlinearities in spot and futures markets.

[11] Partially linear model is a semiparametric regression model. We have not used the nonparametric regression model because sample size is not large enough.

Nonlinear dynamic relations between spot and futures agricultural markets arise due to heterogeneous market participants in spot and futures markets. Participants in spot market are farmers and consumers, whereas the participants in agricultural futures markets are market makers[12], hedge funds, mutual funds, and swap dealers.

The agricultural market participants have different objectives. Non financial traders, such as farmers and consumers, have interest in the physical commodity and thus, trade in the spot market. They also hedge in futures markets. Alternatively, financial traders such as market makers, hedge fund managers, and swap dealers, have interest in the changes in agricultural prices and thus, trade in futures market and speculate on agricultural prices. Financial traders do not have interest in physical commodities.

The agricultural market participants have different investment horizons too. Farmers decide about cropping pattern so, they take a longer term view on crops prices than consumers. We differentiate speculators on the basis of time horizons at which they trade. Market makers trade for shortest time period. They some times operate for a single second. Market makers are not concerned about bull or bear markets, rather they trade with a view to make markets by buying or selling at a very short notice. The objective of the market makers is to purchase futures contracts at a marginally lower price than the existing market price or sell the contracts at a marginally higher price. Speculators are also of different types. They may be day traders or trend followers. These speculators remain in the market for longer period to make profits (Bahattin and Harris 2012). Thus, the microstructure of spot and futures agricultural markets is different, which leads to non-linear causal relationships between them.

Also, nonlinear relationship between spot and futures markets is due to noise traders in futures market. Noise traders are investors who make decisions regarding buy and sell of trades without following economists' advice. Noise traders are irrational investors who do not have diversified portfolio, and often invest in contracts based on their own research. They do not have any inside information and illogically act on

[12] Market makers are speculators, who enters the futures market for a very short time.

noise. They consider noise as an important information that will give them an advantage (Black 1986).

There are many factors that affect the futures and spot markets for agricultural commodity, and that makes it very difficult to hypothesize the functional form relating the prices in these markets. We might get inconsistent results from the wrong parameterization of the regression equation. We estimate the relationship between futures returns as a nonlinear function of the spot returns with lag, and we estimate the relationship between spot returns as a nonlinear function of the futures returns with lag. We are considering the nonlinear model in the parameters. We are not considering the nonlinear relationship between variables[13].

We apply the partial[14] linear (Semiparametric) regression technique to estimate the futures and spot returns relationship. When we take spot (futures) returns as dependent variable, the parametric variables include spot (futures) returns with lag. The futures (spot) returns with lags, which has no parametric specification, is incorporated nonparametrically. We combine the parametric and nonparametric techniques to obtain the semiparametric regression (Partial linear) model.

We then consider the following partial linear model[15]:

$$SP_{ct} = f(FP_{c(t-1)}) + \beta_1 SP_{c(t-1)} + \beta_2 SP_{c(t-2)} + \varepsilon_{c1t} \quad (9)$$

$$FP_{ct} = f(SP_{c(t-1)}) + \beta_1 FP_{c(t-1)} + \beta_2 FP_{c(t-2)} + \varepsilon_{c1t} \quad (10)$$

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[13] If there is nonlinear relationship between variables, we can use linear model with a number of functional forms.

[14] Partially linear model is a semiparametric regression model. We have not used the nonparametric regression model because sample size is not large enough.

[15] Consider the following partial linear (semiparametric) model:

$$y_i = f(x_i) + z_i\alpha + \varepsilon_i$$

$where\ x\ is\ a\ random\ variable, z\ is\ a\ q - dimentional\ random\ variable,$

$(z\alpha) is\ the\ parametric\ term\ and$

$f(x_i)\ is\ the\ non-parametric\ term,\ \ E(\varepsilon|z,x) = 0\ and\ Var\ (\varepsilon|z,x) = \sigma_\varepsilon^2.$

In equation (9), $\beta_1 SP_{c(t-1)}$ and $\beta_2 SP_{c(t-2)}$ are the parametric terms and $f(FP_{c(t-1)})$ is nonparametric term. Similarly, in equation (10), $\beta_1 FP_{c(t-1)}$ and $\beta_2 FP_{c(t-2)}$ are the parametric terms and $f(SP_{c(t-1)})$ is nonparametric term. The function f is a single valued, smooth function.

We have followed the approach of Yatchew difference estimator (1997), to fit the partial linear model. We have used 'lowess' estimators in equations (9) and (10) to estimate the function f. Lowess increases robustness by allotting lower weights to those observations with large residuals and repeating the local regression procedure (Yatchev 2003 p.42).

3.3 Linkages amongst agricultural commodity futures prices

We employ Augmented Dicky-fuller (ADF), Dickey-Fuller generalized least squares (DF-GLS) and Ng-Perron tests to test for the stationarity of the series. We use Johansen Co integration test, Error Correction Model (ECM) and Granger causality analysis to examine the linkages amongst agricultural commodity futures prices. The ECM model is written as:

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-1} + \varepsilon_t$$

Where y_t is a vector whose components are the commodity spot price and the set of futures prices. $\alpha\beta'$ explains the long run impact matrix and $\beta' y_{t-1}$ is the error correction term, Γ_i is the matrices of parameters.

4. The data set

In this study we use futures and spot price data for wheat, barley, maize, gram, mustard, castorseed, soyabean, zeera, chilli, coriander, pepper, sugar and cotton seed oilcake. These are some of the important commodities for our economy and for which data are available. We took the futures and spot price data for these commodities from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai. All data are available on a daily basis for six days a week (barring Sunday, and national holidays), from

August 2009 to September 2014. The rationale for selecting these commodities is straightforward. Wheat is the most important staple foodgrain in India. Maize is a variety of grain which have different uses. It is used as a feed crop and also used in the production of bio-ethanol (fuel). Amongst the maize producing countries in the world, India features in the top ten. Barley comes in the category of cereals, and is used for making health food, beer and soups. We also use barley as a cattle feed. Gram is a very significant pulse crop for which India is the biggest producer in the world. Soyabean is the most widely grown oilseeds in the world and India is the fifth largest soyabean producer worldwide. Sugar (and its by-products) play an important role in India's industrial economy and contribute around 2 percent of GDP. Also, India is the biggest consumer and second biggest producer of sugar in the world. India is the largest exporter of castor oil in the world. Cotton seed oil cake is the by-product obtained after crushing cotton seed for the extraction of oil. We use cotton seed oil cake as a cattle feed because it is a rich source of protein. We use chillies in preparing curries and medicines, and India is the biggest producer of chillies in the world. Indian chillies are of top-quality, and India is also the largest exporter for the same. Coriander comes in the category of spices. It has medical use also. India is one of the major exporter of coriander. Zeera is one of the important spices and India is the biggest producer and consumer. In brief, these crops all play an important role in the Indian economy.

Further, these are the commodities for which futures and spot price data are available from the national exchanges. We realise that there are many other significant commodities that one can think of; however, data are not necessarily available for them. Also, a close look at the commodities traded shows that despite good trading volume, there are frequent trading breaks in the case of some commodities, and so we have not considered those commodities. We have analysed the interlinkages amongst wheat, barley, maize, gram, mustard, castorseed, soyabean, zeera, chilli, coriander, pepper, zeera, and cotton seed oilcake futures prices. We have not considered crop "sugar" for linkages analysis because we have the data for sugar, and not sugarcane. In addition, we have not done intra crop analysis for crop "chilli" because spot price data is missing for several months.

5. Estimation results

5.1. Linear Granger causality test

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 1 and 2 present the linear Granger causality model results for spot and futures returns[16] for all thirteen agricultural commodities. The tables report the chi-squared statistic for the null hypothesis that futures returns do not Granger-cause spot returns; the table 2 reports the chi-squared statistic for the null hypothesis that spot returns do not Granger-cause futures returns. We have selected the optimum lag length according to AIC and BIC criterion. As can be seen from table 1, the null hypothesis that the returns in futures markets does not Granger-cause the returns in spot markets is very strongly rejected in case of all crops : the associated chi-squared statistics turn out to be large with p-value of 0 or close to 0.

However, the null hypothesis that the returns in spot markets do not Granger-cause the returns in futures markets is not rejected for gram, mustard coriander, soyabean, sugar, cotton seed oilcake and: the associated chi-squared statistics turns out to be small. However, in the case of wheat, zeera and barley spot returns Granger-cause futures returns at five percent level of significance.

These findings are consistent with earlier studies 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 return in the spot market today is significantly related to past returns in the futures market, whereas the impact of past spot returns on today's futures return is generally not significant. The information flow from futures to spot markets also appears to have intensified in the past years, because the causal

[16] First difference of the log of prices are returns.

relationship is remarkably strong in comparison to previous studies. This obvious increase in information flows is due to rise in volumes of futures contracts during the past years, which results in more transparent and widely accessible prices.

Changes in futures prices lead to changes in spot prices because of the following reasons: Firstly, in futures market all transactions take place on futures exchanges where the information about the demand and supply of the commodity is collected and acted on, leading to the determination of the equilibrium prices in a competitive manner. Secondly, futures markets allow speculators to take positions in commodities. Without the economic burden of owning the asset (in physical form), speculators trade in futures market. The greater liquidity that speculators bring permits more information to be traded in futures market vis a vis spot market.

Thirdly, lower transaction cost and greater flexibility in futures market, help the futures market to reflect new information more swiftly than the spot market. .

Lastly, various supply and demand shocks impact agricultural prices at different horizons (Schwartz 1997). Supply shocks, such as geopolitical factors, technological advancements, natural disasters etc., can influence agricultural prices at different horizons. For example, a monsoon failure can affect agricultural prices for a month, a war's impact on agricultural prices can last for a year or more, while a technological breakthrough can have a long horizon impact. Similarly, demand shocks such as growth in emerging economies, increasing demand for food grains, extreme climate conditions, etc. can operate at different horizons. However, generally one can argue that demand shocks are more likely to have a long-term effect on agricultural prices while supply shocks[17] are more likely to impact agricultural prices in the short run. These shocks can cause price changes in spot or futures markets or in both markets at the same time. Speculators are the people with better foresight. If speculators transmit these shocks, then futures market will take advantage over spot markets in

[17] Supply shocks can be taken care of by imports of the agricultural goods. Also, supply shocks can have short term effects on agricultural prices due to opening up of the Indian economy to external forces.

over or under reactions to these shocks. Accordingly, futures prices may lead spot prices.

In case of wheat, zeera and barley, there are there bidirectional information flows between spot and futures markets. Price changes in spot markets also lead to price changes in futures markets.

5.2 Partial linear Granger causality test

Granger (1989) argues that nonlinear models represent the correct way to model a real world that is 'almost certainly nonlinear'. The appropriateness of a non-linear model for the data is determined partly from nature of data, and partly from statistical testing. Nature of data in both markets have been explained in previous section. Now we are going to explain statistical testing.

Pretesting for nonlinearity

The appropriateness of a non-linear model for the data is also determined partly from statistical pretesting. Pretesting for nonlinearity protects us from over fitting the data. We have done nonlinear pretesting by using the RESET test, Lagrange Multiplier tests and squared residual test.

A. The RESET test

Ramsey Regression Equation Specification Error Test (RESET)[18] is a general specification test for the linear least squares regression analysis. More precisely, it tests whether non-linear combinations of the fitted values help explain the dependent variable. The Ramsey RESET test tests whether the relationship between the first difference of log of spot price and the explanatory variables is linear or not.

Table 3 presents the T statistic for the null hypothesis. The T statistic for wheat is 2.35 which is significant at 1 percent level of significance. For gram, the t statistic is 4.11, with p-values of 0. Similarly, for other crops except maize, the calculated statistic is

[18] For further details on the RESET carried out, refer to the appendix C.

significant. Therefore, there is non-linearity in the regression equation for all crops except maize, and we conclude that the linear model for the first difference of log of spot price is not appropriate for all crops except maize.

B. Lagrange Multiplier test for non-linearity

We use Lagrange Multiplier tests[19] to test for a specific type of nonlinearity. The table 4 presents the F-statistic results of LM test. The F-statistic for wheat is 7.40, with p value of 0. For gram, the F-statistic is 8.40, with p-values of 0. Similarly, for sugar barley, maize, gram, mustard, coriander, zeera, castorseed, soyabean, zeera, cotton seed oilcake and pepper, the calculated statistic is significant. However, for mustard, the calculated value is 0.44 which is not significant.

It can be seen from LM test results, that the null hypothesis of linearity is very strongly rejected for wheat, barley, maize, gram, zeera, coriander, castorseed, soyabean, sugar, cotton seed oilcake and pepper. This indicates that there is non-linearity in the regression equation for these crops. The nonlinear functional form in these crops are Generalised auto regressive (GAR) model. We are not able to reject the LM test for mustard. This means that crop mustard has not satisfied the GAR nonlinear functional form. The use of LM test helps us in selecting the form of non-linearity. It could be the case that LM test rejects the GAR model but it can accept bilinear model (BL) model. (Enders 2014, p. 417). Bilinear model (BL) is a high order of Generalised auto regressive model GAR model. In the BL model, there is a moving average (MA) term and interactions of autoregressive and MA terms. We have not performed the BL form of non-linearity.

C. The Ljung-Box squared residual test

Q-statistic of squared residuals is a nonparametric test[20]. The Ljung-Box statistics is used to the squared residuals of ARMA model to examine model adequacy. Table 5

[19] For further details on the LM tests carried out, refer to the appendix C.

[20] The reset test and Lagrange multiplier tests show that the causal relation between spot and futures prices are nonlinear, but we still can do parametric estimation. So, we performed squired residual test which is a nonparametric test. For further details on the squared residual tests carried out, refer to the appendix C.

presents the Q-statistic results of squared residual test. The hypothesis that there is linearity in the regression equation is very strongly rejected in case of all crops except maize and cotton seed oil cake. This indicates that there is non-linearity in the regression equation for all crops except maize and cotton seed oil cake. We, therefore, conclude that the linear model for the first difference of log of spot price is not appropriate for wheat, barley, gram, mustard castorseed, soyabean, zeera, coriander, pepper and sugar.

Granger causality test for partial linear model

Financial theory does not suggest a particular functional form for spot and futures market for a model specification. We may get inconsistent estimates from incorrect parameterization of the regression equation. So, we have used the partial linear model to obtain consistent estimates of the parameters of interest. Table 6 and 7 presents the partial linear Granger causality test results for spot and futures returns[21] for all thirteen agricultural commodities. The table 6 reports the chi-square statistic for the null hypothesis that futures returns does not partially Granger-cause spot returns; the table 7 reports the chi-square statistic for the null hypothesis that spot returns does not partially Granger-cause futures returns. The chi-square statistic for wheat is 8.35, with p value of 0 (table 6). For gram, the chi-square statistic is 12.42, with p-values of 0. Similarly, for barley, coriander, castorseed, zeera, soyabean, sugar, cotton seed oilcake and pepper, the calculated statistic is significant. However, for maize and mustard, the calculated values are 0.04 and 1.23, which are not significant.

This indicates that (table 6), even after removing the linear dependence, futures returns partially Granger-cause spot returns for barley, gram, coriander, castorseed, zeera, soyabean, sugar, cotton seed oilcake and pepper. Futures returns and spot returns for maize and mustard are said to independent because first lag of the log of prices are insignificant in the partial linear equation for the other variables. There is no partial linear Granger causality for maize and mustard because the t-statistic is insignificant. No partial linear Granger causality indicates no price discovery process for maize and mustard. Also, spot returns does not partially Granger-cause futures

[21] First difference of the log of prices are returns.

returns for all crops except barley (table 7). In sum, the partial linear Granger causality results provide no evidence of nonlinear causality from changes in spot prices to changes in futures prices. However, there is strong nonlinear causal relationship from futures to spot markets for wheat, gram, castorseed, soyabean, sugar, zeera, and pepper. In case of barley, the partial linear causal relationship is bi-directional.

Comparison fully parametric model with a quadratic polynomial with partial linear model

We have also compared the parametric model with a quadratic polynomial with partial linear model to find the effect of exogenous variable between these two specifications.

The estimation of the fully parametric model with a quadratic polynomial of the first lag of the first difference of the log of futures prices shows that although the effect of exogenous variables is qualitatively similar between these two specifications, the magnitude of some coefficients are different (table 8,9,10,11). The effect of first lag of the first difference of the log of wheat spot prices declines from 0.22 in the fully parametric model to 0.13 in the partial linear model (Table 8). We have not reported the comparisons for remaining eight crops because we are getting the same results.

Graphs 1 and 2 illustrates the nonparametric and fully parametric estimates of first difference of log of spot price plotted against first lag of the first difference of futures price for castorseed and sugar respectively. We find that the quadratic specification fits the data closely to the nonparametric specification.

5.3 Linkages amongst agricultural commodity futures prices

We performed Augmented Dicky-fuller (ADF), Dickey-Fuller Generalized Least squares (DF-GLS) and Ng-Perron tests to examine the unit root[22] in the data. These tests show that the futures prices of all agricultural commodities are integrated of order one. There is the dominance of stochastic trend in the log of futures prices of all the twelve agricultural commodities. However, the series become stationary after the first difference. Since the first difference of the futures prices of all the agricultural

[22] We have not reported unit root results.

commodities are I(0), it can be stated that the futures prices of all the twelve agricultural commodities in levels are not I(2) processes.

The information about the optimum lag length in the series has been given by AIC and BIC criterion. The trace test and maximal eigenvalue test denote that the null hypothesis of no co-integration among the log of agricultural commodity prices is rejected (Table 12). We find that the trace test statistic of 340.19 substantially exceeds the critical value of 334.98, and therefore, null hypotheses of no co-integrating vector is rejected. The maximal eigenvalue test statistic is 76.90, which is significant at 5 percent level of significance. These two tests reveal that the log of agricultural commodity futures prices have a long term (co-integrating) relationship. It implies that there is a co-movement amongst the log of futures prices of wheat, barley, maize, gram, mustard chilli, coriander, castorseed, soyabean, zeera, cotton seed oilcake and pepper. The long term (co-integrating) relationship among the log of agricultural commodity prices would prevent the log of futures prices of all the twelve agricultural commodities from wondering apart without bounds. (Brooks 2002, p.421).

We, then conducted error correction tests to examine short run causal relationship. However, we could not find any short term causal relationship amongst the first difference of log of agricultural commodities futures prices (Table 13). Therefore, we conducted granger causality tests. We could not find a clear pattern from the granger causality tests too. Nevertheless, we found that the first difference of log of wheat futures price granger causes the first difference of log of mustard, maize, coriander, chilli, barley, and soyabean futures price. This implies that wheat futures market dominated over the mustard, maize, coriander, chilli, barley, and soyabean futures markets (Table14). Similarly, the first difference of log of gram futures price Granger causes the first difference of log of mustard, barley chilli futures price (Table14), implying that the gram futures market dominated over the mustard, barley and chilli futures markets.

6. Conclusions and policy implications

Using daily data on spot and futures prices for wheat, barley, maize, gram, mustard castorseed, soyabean, zeera, chilli, coriander, pepper, cotton seed oilcake and sugar, this study estimates linear and partial linear Granger models to examine the lead–lag relationship between the prices. The evidence provided by linear Granger causality results suggest 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. In case of wheat, zeera and barley, there are bi-directional information flows between the spot and futures markets.

However, there is non-linear dynamic relationship between the prices of the spot and futures markets. Considering then, that the linear causality tests might overlook nonlinear dynamic relations, we conducted partial linear causality tests proposed by Yatchew (1997). The partial linear causality results provide no evidence of nonlinear causality from changes in spot prices to changes in futures prices for the sample crops. If there is any strong nonlinear causal relationship, it is from futures to spot markets, at least for wheat, gram, castorseed, soyabean, sugar, zeera, and pepper. In case of barley, the partial linear causal relationship is bi-directional.

Thus, the basic finding of this study is that the futures market performs the role of price discovery[23] . This is consistent with previous findings of Garbade and Silber (1983), Moosa (2002) and Harnandez and Torero (2010). Garbede and Silver (1983) have analysed the agricultural and non-agricultural commodities traded on various exchanges in USA. Their study conclude that futures markets do approximately 75 percent of price discovery function. Moosa (2002) has analysed daily spot and futures price data of crude oil from January 1985 to 11 July 1996, traded on the New York Merchantile Exchange. His findings reveal that “about 60 percent of new information is reflected first in futures prices”. Harnandez and Torero (2010) have examined the weekly data of agricultural commodities from January 1994 to June2009, traded in the Chicago board of trade. Harnandez and Torero (2010) have also examined the nonlinear relationship between spot and futures markets, and found that futures

[23] This means that spot price move towards futures price

market performs the role of price discovery. In addition, this finding is also in line with that of Sehgal, Ahmad and Deisting (2014), who have examined the recent Indian agricultural data and found the causal relationship from futures to spot market. However, Sehgal, Ahmad and Deisting (2014) have not examined the nonlinear causal relationship between the futures and spot markets.

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.

The trace test and maximal eigenvalue test reveal that agricultural commodity futures prices have a long term (co integrating) relationship. However, we could not observe any short term causal relationship even among the related agricultural commodities.

The movement of futures agricultural commodity prices are interdependent because the agricultural commodity prices are linked through substitutability and complementarity in demand and supply. Furthermore, specific macroeconomic factors such as aggregate demand, inflation, exchange rates and interest rate, and herd behaviour in financial markets causes the co movement of agricultural commodity prices (Malliaris and Urrutia 1996).

Futures market performs the function of price discovery. The interdependencies amongst the futures prices of the agricultural commodities reveal that the price discovery in the futures market of one commodity signals useful information that is relevant for other linked commodity futures markets. For example, the findings suggest that wheat futures price have a long term impact on the futures prices of barley, maize, gram, mustard chilli, coriander, castorseed, soyabean, zeera, cotton seed oilcake and pepper. This implies that the price discovery in wheat futures market provides the useful information not only to the underlying wheat spot commodity market but also to the spot markets of barley, maize, gram, mustard chilli, coriander, castorseed, soyabean, zeera, cotton seed oilcake and pepper. This information might include several factors such as substitutability and complementarity in demand and supply, shocks, weather, herd behaviour (Malliaris and Urrutia 1996). Besides, the linkages amongst the agricultural commodity futures prices will also promote cross hedging and cross speculation across the markets.

This finding differs from the findings of Booth and Ciner (2001). The authors have found that there is a pair wise cointergrating relationship between barley and wheat that share strong economic factors. However, there is no pairwise co integrating relationship between barley, cocoa, sugar, coffee and wheat. So, they concluded that there is no evidence of herding trends among the Tokyo agricultural commodity futures markets. Their conclusion is that the long term co movement is not due to the herd behaviour, but due to common economic factors among the related agricultural commodity prices. Nonetheless, this finding is consistent with the findings of Malliaris and Urruntia (1996). Malliaris and Urruntia (1996) have found the significant pairwise linkages among the agricultural commodities futures pieces traded on the Chicago board of trade (CBOT).

My study adds to the existing literature in the following ways: Firstly, my study captures the real world causal relationship between spot and futures agricultural commodity markets by incorporating partial linear model, whereas the past studies on Indian commodity markets have shown ideal world causal relationship by employing linear Granger causality test. Secondly, compared to previous studies, the identified causal relationship from futures to spot markets appears to be stronger[24] in my study. This result implies that the information flow from futures to spot markets has intensified in the past 5 years, due to the increase in the the trading volume in futures. Fourthly, my study's finding has vital connotations for alternative instruments proposed to tackle disproportionate volatility in commodity markets. Especially, Von Braun and Torero (2008, 2009) have suggested the enactment of a global virtual reserve to minimize speculative attacks and prevent too much spikes in commodity spot prices. The objective is to identify a price band that would be a warning sign to speculators that a market evaluation is expected if futures prices surpass the upper limit of this band. If, in spite of the signal, there is proof of too much price spike, a progressive number of short sales[25] in the futures market will then be effected so that futures and eventually

[24] For all crops, the associated statistic is large with p- Value of 0 or close to 0.
[25]Selling futures contracts over a specific period of time and delivering of commodity at a later date at the specified price. The specified price will be the market price.

spot prices will decline to fair levels. My finding is that changes in futures prices lead to changes in spot prices. This reality strengthens the feasibility of this innovative intervention mechanism. Lastly, this study also finds the significant linkages amongst the agricultural commodity futures prices, which suggests that the price discovery in the futures market of one commodity provides the useful information not only to the underlying spot commodity market but also to the related spot commodity markets. The previous studies have examined the price discovery process between the spot and futures prices of a specific commodity only and have not considered the interdependence of futures prices of various crops traded on the national commodity exchanges.

The following policy implications result from this paper. Firstly, in an open economy, global supply-demand related factors influence the domestic markets whether futures trading is allowed or not. Futures market is one tool which helps in establishing true equilibrium in Indian agricultural commodity prices. So, authorities should not see the futures market with scepticism and should not raise questions regarding its benefits. Secondly, authorities need to reach out to farmers through post offices, banks and inform futures price to farmers on daily basis so that farmers can decide about its cropping pattern, can increase their income by deciding whether to hold the commodity or sell depending on the price signals from futures market. Thirdly, authorities need to start futures trading in other agricultural commodities also. Fourthly, authorities need to provide infrastructure such as warehousing, finance etc. to farmers so they can take decision to sell or hold back their produce at the time of harvest when prices are low. Fourthly, the futures market has to be anchored to spot market. The spot markets have large number of weaknesses. Till these weaknesses are improved, it will be hard for the futures market to grow far ahead of them. Whenever futures markets try to grow faster than spot markets, any gap between the two gets broadened, then speculators will exploit the markets. So, authorities need to remove the rigidities of spot markets. Lastly, the findings of this study have significant policy implications for stock brokers, traders, mill owners and speculators. The futures prices of agricultural commodities are interdependent. This means that the price discovery of one particular commodity provides valuable information about other commodities. Therefore, the stock brokers, and speculators should rely on the co-movement of agricultural commodity prices (Pindyck and Rotemberg 1990).

Appendix A

Table 1

Granger causality tests of daily returns in spot and futures markets, 2009-2014

Null Hypothesis: First difference of futures price does not Granger cause first difference of log of spot price			
Crops	Lags	Chi-Square	Probability
Wheat	1	11.68	0.00
Soyabean	1	113.35	0.00
Gram	1	92.01	0.00
Zeera	8	15.27	0.05
Castorseed	2	213.91	0.00
Sugar	2	127.87	0.00
Barley	2	44.44	0.00
Maize	4	12.55	0.01
Mustard	2	6.87	0.03
Coriander	2	48.67	0.00
Pepper	2	424.7	0.00
Cotton seed oilcake	1	3.12	0.07

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. We have selected lags according to the Akaike Information criterion (AIC) and Bayesian Information Criterion (BIC). Period of analysis: May 2009 – August 2014 for all crops.

Table 2

Granger causality tests of daily returns in spot and futures markets, 2009-2014

Null Hypothesis: First difference of spot price does not Granger cause first difference of futures price			
Crops	Lags	Chi-Square	Probability
Wheat	1	11.22	0.00
Gram	1	2.02	0.15
Zeera	8	115.21	0.00
Castorseed	2	4.97	0.08
Sugar	2	1.46	0.48
Soyabean	1	0.74	0.55
Barley	2	19.40	0.00
Maize	4	8.53	0.07
Mustard	2	1.79	0.40
Coriander	2	3.58	0.16
Pepper	2	4.64	0.09
Cotton seed oilcake	1	0.00	0.99

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. We have selected lags according to the Akaike Information criterion (AIC) and Bayesian Information Criterion (BIC). Period of analysis: May 2009 – August 2014 for all crops.

Table3

Ramsey RESET Test, 2009-2014

Crops	T-statistic
Wheat	2.35 ***
Gram	4.11 ***
Zeera	4.04 ***
Castorseed	4.15 ***
Sugar	2.80 ***
Soyabean	5.84 ***
Barley	2.34 **
Maize	1.34
Mustard	21.22 ***
Coriander	10.65 ***
Pepper	2.01 **
Cotton seed oilcake	3.75 ***

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. We have used the RESET test for nonlinear pretesting. Ramsey Regression Equation Specification Error Test (RESET) is a general specification test for the linear least square regression analysis. The Ramsey RESET test tests whether the relationship between the first difference of log of spot price and the explanatory variables is linear or not. Period of analysis: May 2009 – August 2014 for all crops. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 4

Lagrange Multiplier test, 2009-2014

Crops	F-statistic
Wheat	7.40 ***
Gram	8.40 ***
Zeera	65.78 ***
Castorseed	2.76 ***
Sugar	115.04 ***
Soyabean	53.64 ***
Barley	215.94 ***
Maize	7.31 ***
Mustard	0.44
Coriander	2.80 **
Pepper	2.04 *
Cotton seed oilcake	6.18 ***

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. We have used the Lagrange Multiplier tests for nonlinear pretesting. Lagrange Multiplier tests is used to test for a specific type of nonlinearity. We check whether returns have the particular Generalised auto regressive (GAR) specification. Period of analysis: May 2009 – August 2014 for all crops. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5

The Ljung-Box squared residual test, 2009-2014

Crops	Q-statistic	Probability
Wheat	61.40	0.00
Gram	57.37	0.00
Zeera	39.88	0.00
Castorseed	48.45	0.00
Sugar	117.15	0.00
Soyabean	4.59	0.03
Barley	74.93	0.00
Maize	2.29	0.80
Mustard	63.10	0.00
Coriander	70.78	0.00
Pepper	166.86	0.00
Cotton seed oilcake	0.00	1.00

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. We have used the squared residual test for nonlinear pretesting. Q-statistic of squared residuals is a nonparametric test. The Ljung-Box statistics is used to examine the model adequacy. Period of analysis: May 2009 – August 2014 for all crops.

Table 6

Partial Linear Granger causality tests of daily returns in spot and futures markets, 2009-2014

Null Hypothesis: First difference of log of futures price does not partially Granger cause first difference of log of spot price		
Crops	T-ratio	Probability
Wheat	8.35	0.00
Gram	12.42	0.00
Zeera	7.40	0.00
Castorseed	2.08	0.00
Sugar	5.05	0.00
Soyabean	4.93	0.00
Barley	2.81	0.00
Maize	0.04	0.48
Mustard	1.23	0.11
Coriander	1.39	0.08
Pepper	17.01	0.00
Cotton seed oilcake	1.89	0.02

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. Period of analysis: May 2009 – August 2014 for all crops. No. of lags is one

Table 7

Partial Linear Granger causality tests of daily returns in spot and futures markets, 2009-2014

Null Hypothesis: First difference of log of spot price does not partially Granger cause first difference of log of futures price		
Crops	T-ratio	Probability
Wheat	0.99	0.16
Gram	0.82	0.20
Zeera	0.53	0.29
Castorseed	1.12	0.13
Sugar	0.42	0.59
Soyabean	0.93	0.23
Barley	2.53	0.00
Maize	-2.92	0.99
Mustard	-0.98	0.83
Coriander	0.12	0.45
Pepper	0.86	0.19
Cotton seed oilcake	0.92	0.17

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: Note: All variables are the first difference of the log of prices. First difference of the log of prices are returns. Period of analysis: May 2009 – August 2014 for all crops. No. of lags is one

Table 8

Comparison of quadratic model with partial linear model for wheat

	Partial linear model	Parametric model with quadratic polynomial
$Variables$	$Dependent\ Var: dlnSP_w$	$Dependent\ Var: dlnSP_w$
$dlnFP_w1$		0.348 ***
$(dlnFP_w1)^2$		-0.003
$dlnSP_w1$	0.133 ***	0.227 ***
$dlnSP_w2$	-0.0449	-0.0286
$constant$		
Observations	1529	1530

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: The variables are the first difference of the log of spot price of wheat $(dlnSP_w)$ and the first difference of the log of futures price of wheat $(dlnFP_w)$. First difference of the log of prices are returns. Period of analysis: May 2009 – August 2014 for all crops.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 9

Comparison of quadratic model with partial linear model for gram

	Partial linear model	Parametric model with quadratic polynomial
$Variables$	$Dependent\ Var: dlnSP_G$	$Dependent\ Var: dlnSP_G$
$dlnFP_G1$		0.182 ***
$(dlnFP_G1)^2$		-0.473 ***
$dlnSP_G1$	0.113 ***	0.002
$dlnSP_G2$	-0.090 ***	-0.076 ***
Observations	1514	1514

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: The variables are the first difference of the log of spot price of gram $(dlnSP_G)$ and the first difference of the log of futures price of gram $(dlnFP_G)$. Period of analysis: May 2009 – August 2014 for all crops. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 10

Comparison of quadratic model with partial linear model for sugar

	Partial linear model	Parametric model with quadratic polynomial
$Variables$	$Dependent\ Var: dlnSP_s$	$Dependent\ Var: dlnSP_s$
$dlnFP_s1$		0.240 ***
$(dlnFP_s1)^2$		-0.550
$dlnSP_s1$	0.062 *	0.898 ***
$dlnSP_s2$	-0.039	-0.002
Observations	1041	1042

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: The variables are the first difference of the log of spot price of sugar $(dlnSP_s)$ and the first difference of the log of futures price of sugar $(dlnFP_s)$. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 11

Comparison of quadratic model with partial linear model for castorseed

	Partial linear model	Parametric model with quadratic polynomial
$Variables$	$Dependent\ Var: dlnSP_{cs}$	$Dependent\ Var: dlnSP_{cs}$
$dlnFP_{cs}1$		0.398 ***
$(dlnFP_{cs}1)^2$		-2.312 ***
$dlnSP_{cs}1$	-0.185 ***	-0.112 ***
$dlnSP_{cs}2$	-0.005	-0.028
Observations	1366	1367

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: The variables are the first difference of the log of spot price of castorseed ($dlnSP_{CS}$) and the first difference of the log of futures price of castorseed ($dlnFP_{CS}$). ****, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 12.
Johansen's Co-integration Tests for daily prices in agricultural futures markets, 2009-2014

Multivariate Tests		Trace test		Maximal Eigen Value	
Natural log of futures price of Crops	Ranks	Calculated Value	Critical Value (0.95)	Calculated Value	Critical Value (0.95)
Wheat, barley, maize, gram, mustard, castorseed, soyabean, zeera, chilli, coriander, pepper, zeera and cotton seed oilcake.	$H_0: r = 0$	340.19 **	334.98	76.90 **	76.57
	$H_0: r \leq 1$	263.28	285.14	70.62 **	70.53
	$H_0: r \leq 2$	192.65	239.23	39.81	64.50

Note: Trace test indicates one co-integrating equation at the 0.05 level, whereas Maximal Eigen Value test indicates two co-integrating equations at the 0.05 level. All the variables are in natural log. The number of lags is two. Period of analysis: May 2009 – August 2014 for all crops.
** indicates statistical significance at the 5% level.

Table 13:
ECM Statistics for daily returns in agricultural futures markets, 2009-2014

	First difference of the log of future price (dependent variable)											
	Barley	Castor seed	Chilli	Coriander	Cotton	Gram	Maize	Mustard	Pepper	Soyabean	Wheat	Zeera
α_c	-.005	0.002	-0.006	0.012 **	-0.02 ***	-0.011**	0.006	0.002	-0.005	0.013 ***	-0.006 **	-0.008 **
Barley lag1	-0.27 ***	-0.01	0	0	0	-0.05	0.03	-0.01	0	-0.01	-0.02	0.01
Barley lag 2	-0.019	-0.03	0	-0.05	0.02	0	0.03	-0.01	-0.01	-0.03	0	0
Castor seed lag1	0.07	0.12 ***	0.05	0.02	0.02	0.05	0.03	0	-0.02	-0.02	-0.02	-0.02
Castor seed lag 2	-0.07	-0.07 *	0	-0.03	0.11 *	-0.11 **	0.03	0	0	0	-0.05 *	0.01
Chilli lag1	0.04	-0.03	0.13 ***	0.03	0.02	-0.09 ***	0	-0.04 *	0.01	-0.05 *	0	0
Chilli lag 2	-0.01	0.04	-0.05	0.02	-0.04	0.05	0	0.02	0.02	0	-0.01	-0.02
Coriander lag1	-0.01	-0.05 *	0.01	0.04	-0.02	0.01	0	-0.03	-0.04	-0.04	-0.02	-0.01
Coriander lag 2	0.03	0	0.06	0.01	-0.06	-0.03	-0.01	0	0.02	0	-0.01	-0.01
Cotton seed lag 1	-0.03	0.03	0	0.04	0.02	-0.03	0.04 *	0	0.01	-0.01	0	0
Cotton seed lag 2	-0.01	0.01	0	0.01	0	0	-0.01	0	0	0.01	0	-0.02
Gram lag1	0.01	0.06	-0.03	-0.01	0.14 **	-0.23 ***	-0.05	-0.03	-0.04	-0.03	-0.01	-0.01
Gram lag 2	0.07	-0.04	0.08 *	0.04	-0.17 ***	-0.02	0	0.06 **	0.03	0.05	0.02	0.01
Maize lag1	-0.01	0	0.05	0.02	-0.04	0.05	-0.42 ***	0	-0.01	0	0.03	-0.01

Table 13 (Continued)												
Variables	Barley	Castor seed	Chilli	Coriander	Cotton	Gram	Maize	Mustard	Pepper	Soyabean	Wheat	Zeera
Maize lag 2	-0.05	-0.01	-0.02	0.03	-0.01	0.03	0	-0.02	0	-0.02	0	-0.01
Mustard lag1	0.03	0.02	0.05	0.05	-0.17 *	0.27 ***	0.11 *	0.04	-0.02	0.02	0.02	0.07
Mustard lag 2	0.08	0.14 **	0	0.03	0.18 *	0.09	0	-0.05	0.03	0.03	0	0
Pepper lag1	0.23	-0.07 *	-0.04	0.08	-0.13 **	-0.05	-0.02	0.01	0.11 ***	0	-0.01	0.06
Pepper lag 2	-0.07	0.06	-0.01	0	-0.02	-0.05	-0.09 **	-0.01	0	-0.06 *	-0.03	0
Soyabean lag1	0.02	0	0.01	-0.03	0.13 *	-0.07	0.11 **	-0.01	0.01	0.01	0.06 *	-0.01
Soyabean lag 2	0.02	-0.08 *	-0.09	-0.03	-0.10	0.08 *	0.05	0.02	-0.06	-0.05	0.01	-0.01
Wheat lag1	0.03	0.06	-0.20 ***	-0.26 ***	0.14	-0.2 ***	0.06	-0.02	-0.05	-0.02	-0.07 *	-0.17 **
Wheat lag 2	0.07	0.01	0.03	0.13	0.12	-0.02	0.09	0.14 ***	0.02	0.15 ***	0.04	0.04
Zeera lag1	0.06	0.09 **	0	0.08	0	0.05	0.11 ***	0.09 ***	0.07 *	0.14 ***	0.02	0.01 **
Zeera lag2	-0.03	0	-0.05	0	0.12 *	0	0	-0.05	-0.06	-0.01	0.02	-0.04
Constant	0.00	0	0	0	0	0	0	0	0	0	0	0

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

Note: All variables are the first difference of the log of futures prices (FP). First difference of the log of prices are returns. α_C denotes the long run coefficients. "Cotton" refers to cotton seed oil cake. Period of analysis: May 2009 – August 2014 for all crops. Two lags are taken for all crops.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 14
Pair wise Granger Causality Test of daily returns in agricultural futures markets, 2009-2014

Null Hypothesis: First difference of log of futures price of one crop does not Granger cause first difference of log of futures price of other crop												
	First difference of the log of future price (dependent variable)											
	Barley	Castor seed	Chilli	Coriander	Cotton	Gram	Maize	Mustard	Pepper	Soyabean	Wheat	Zeera
Barley	NA	1.37	0.03	0.32	0.12	1.90	4.5 ***	0.27	0.14	0.59	0.87	0.13
Castorseed	3.55 **	NA	0.40	0.89	2.59 *	2.45 *	5.38 ***	0.06	0.19	0.64	1.47	0.26
Chilli	2.55*	1.61	NA	0.87	0.48	2.77 *	2.25	2.74 *	0.52	1.56	0.18	0.80
Coriander	2.10	0.54	0.96	NA	0.38	0.36	4,72 ***	1.59	1.77	1.23	0.54	2.03
Cotton	1.53	0.70	1.18	2.87 *	NA	0.38	1.46	1.37	1.83	0.32	0.11	1.47
Gram	4.83 ***	2.28 *	3.40 **	1.17	4.61 ***	NA	0.69	4.18 ***	2.77 *	2.36 *	1.06	0.80
Maize	1.15	0.12	0.72	0.29	0.13	0.58	NA	0.44	0.62	0.14	1.19	0.88
Mustard	5.30 ***	2.50 *	0.07	0.27	0.81	5.27 ***	10.6 ***	NA	1.05	0.75	0.89	0.21
Pepper	1.97	0.53	0.67	1.35	0.76	0.51	4.75 ***	0	NA	0.99	0.25	1.74
Soyabean	1.95	0.09	1.38	0.05	0.65	0.99	15.1 ***	0.07	1.17	NA	2.31 *	0.72
Wheat	3.31 **	0.81	4.53 *	5.79 ***	2.19	1.54	4.40 ***	6.27 ***	2.19	3.94 ***	NA	5.64 ***
zeera	4.31**	2.11	0.06	2.00	0.45	0.29	11.0 ***	1.11	0.44	2.58 *	0.94	NA

Source: Author's estimation based on secondary data from the National Commodity and Derivative Exchange (NCDEX), Mumbai, and the Multi-Commodity Exchange (MCX), Mumbai.

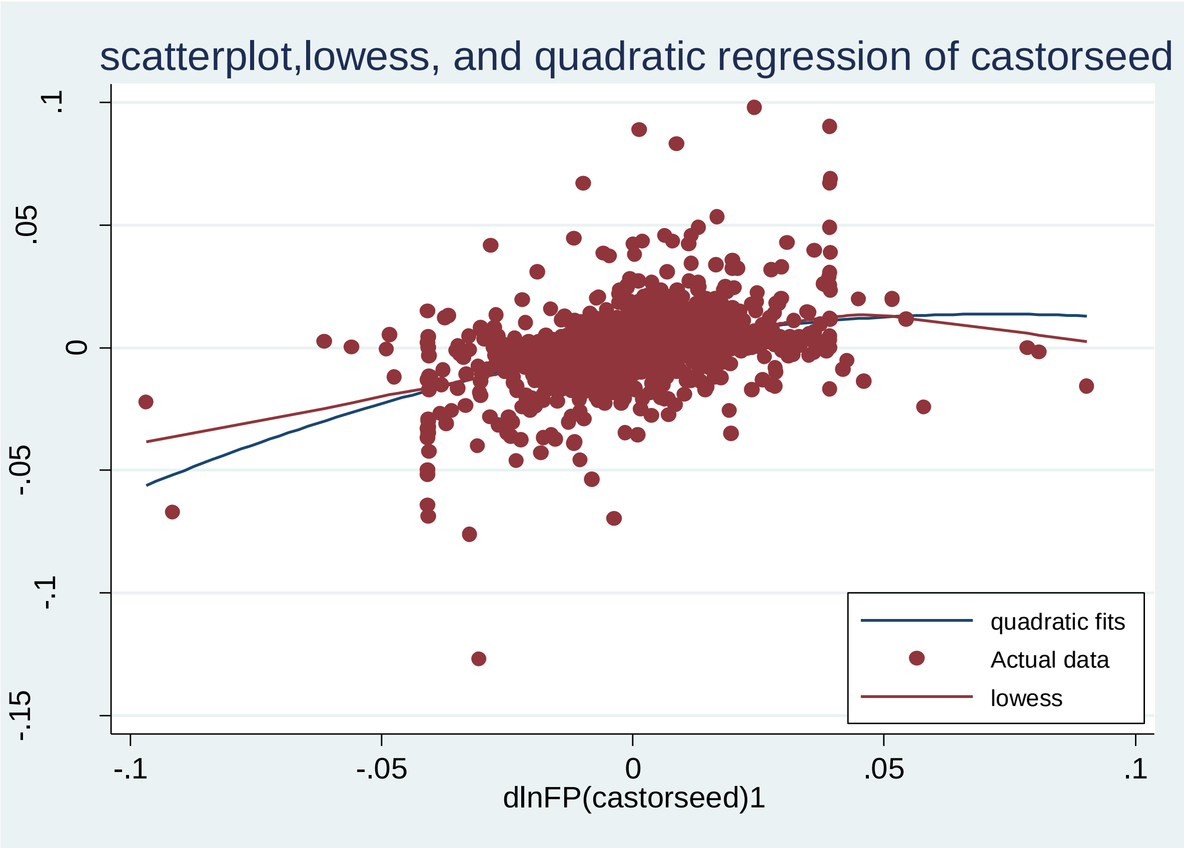
Note: All variables are the first difference of the log of futures prices (FP). First difference of the log of prices are returns. "Cotton" refers to cotton seed oil cake. F- statistic reported. Period of analysis: May 2009 – August 2014 for all crops. Two lags are taken for all crops.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Appendix B

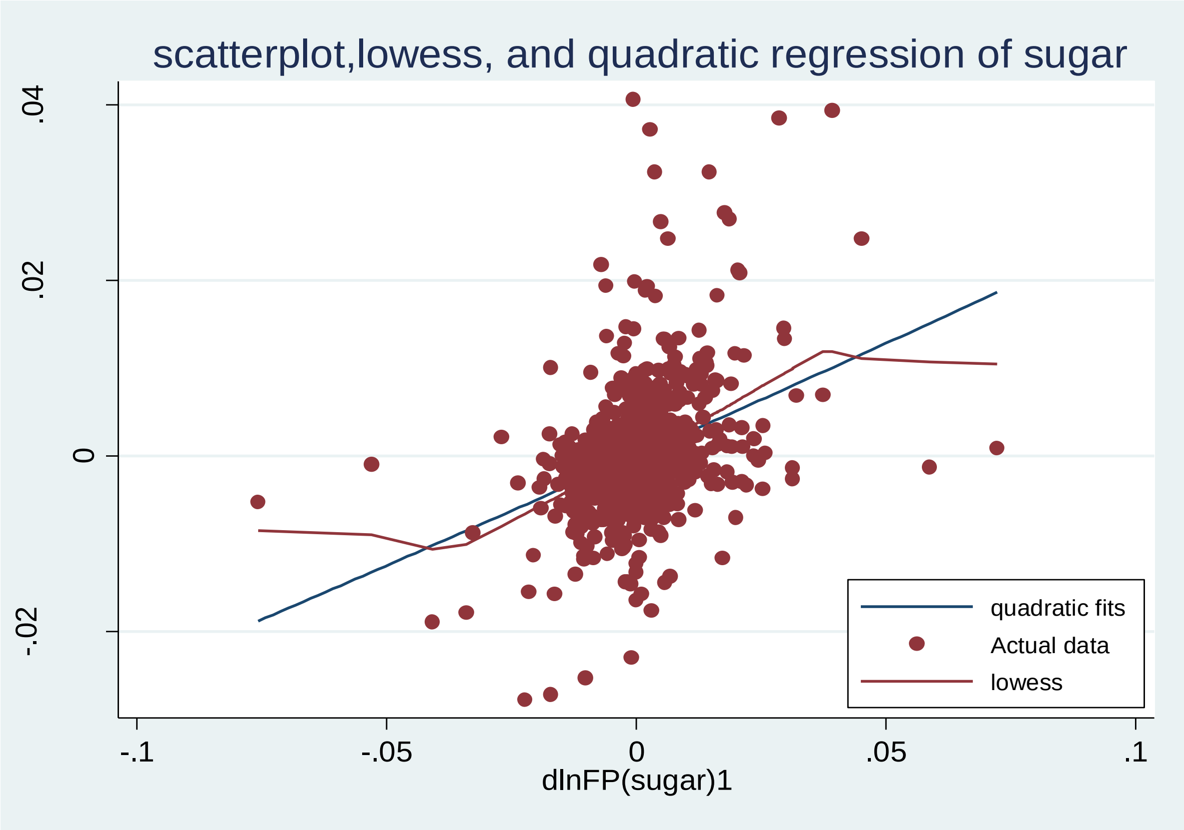
Graph 1

First difference of log of spot price plotted against first lag of the first difference of futures price for castorseed



Graph 2

First difference of log of spot price plotted against first lag of the first difference of futures price for sugar



Appendix C

Pretesting for nonlinearity

We have done nonlinear pretesting by using the RESET test, Lagrange Multiplier test and squared residual test.

The RESET test

Ramsey Regression Equation Specification Error Test (RESET) test is a general specification test for the linear least squares regression analysis. More precisely, it tests whether non-linear combinations of the fitted values help explain the dependent variable. The intuition behind the test is that if non-linear combinations of the explanatory variables have any power in explaining the dependent variable, then linear model is mis-specified.

Consider the model

$$\hat{y} = E\{y|x\} = \beta x$$

The Ramsey test then tests whether $(\beta x)^2, (\beta x)^3, \ldots (\beta x)^k$ has any power in explaining y. This is executed by estimating the following regression equation.

$y = \alpha x + \gamma_1 \hat{y}^2 + \cdots + \gamma_{k-1} \hat{y}^k + \varepsilon,$

and then testing, whether γ_1 through γ_{k-1} are zero. If the null-hypothesis that all γ coefficients are zero is rejected, then the model suffers from mis-specification.

Lagrange Multiplier test for non-linearity

We use Lagrange Multiplier tests to test for a specific type of nonlinearity. (Enders 2014, p.417). Assuming that $f(\,)$ be the non linear functional form and suppose α

represent the parameters of $f()$, then we have conducted LM test as follows:

Step 1: we have estimated the linear portion of model and got the residual e_t. We would like to check whether y_t has the particular Generalised auto regressive (GAR) specification:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-1} y_{t-2} + \varepsilon_t$$

Step 2 : we found the partial derivatives of the nonlinear functional form under Null hypothesis that the model is linear. After that we estimated the regression by regressing e_t on these partial derivatives.

$$e_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + a_3 y_{t-1} y_{t-2} + \vartheta_t$$

Then we performed an F-test for the joint hypothesis $a_0 = a_1 = a_2 = a_3$.

The use of a number of LM test helps us in selecting the form of non-linearity. It might be that LM test rejects the GAR model but it can accept bilinear model (BL). (Enders 2014, p. 417). GAR is a non-linear auto regressive model. Bilinear model (BL) is a high order of Generalised auto regressive model GAR model. In the BL model, there is a moving average term and interactions of autoregressive and MA terms. The bilinear model (BL) has the following form:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 \varepsilon_{t-1} y_{t-1} y_{t-2} + \varepsilon_t$$

The Ljung-Box squared residual test

Q-statistic of squared residuals is a nonparametric test.[26] The Ljung-Box statistics is used to the squared residuals of ARMA model to examine model adequacy (Tsay 2010, p.206). The test statistic is

$$Q(m) = T(T+2) \sum_{i=1}^{m} \frac{\hat{\rho}_i^2(a_t^2)}{T-i}$$

Where T is the sample size, m is the number of autocorrelations used in the test, a_t denotes the residual series, and $\hat{\rho}_i(a_t^2)$ is the lag-i auto correlation function of (a_t^2). We estimate the following regression

$$a_t^2 = \beta_1 + \beta_1 a_{t-1}^2 + \cdots + \beta_m a_{t-m}^2 + \varepsilon_t$$

The null hypothesis is β_1 through β_m should be zero, implying no nonlinearities.

The parametric model with quadratic polynomial

$$SP_{ct} = \alpha_1 FP_{c(t-1)} + \alpha_2 (FP_{c(t-1)})\text{^}2 + \beta_1 SP_{c(t-1)} + \beta_2 SP_{c(t-2)} + \epsilon_{c1t}$$

[26] The reset test and Lagrange multiplier tests show that the causal relation between spot and futures prices are nonlinear, but we still can do parametric estimation. So, we performed squatted residual test which is a nonparametric test.

In the above equation the first lag of the first difference of the futures price enters the model as a quadratic term.

Appendix D

Meaning of price discovery

Price discovery is an abstract concept and not easily subject to empirical demonstrations. However, this is a very important concept. Price discovery is the ability of the market to discover true equilibrium prices (Edward and Ma 2003, p. 163).

There is a difference between price discovery and price equilibrium. Equilibrium can be in one market or there can be simultaneous equilibrium in both[27] markets. Equilibrium means the price at which total demand equals total supply. Price discovery is a much broader concept. When same commodity is traded in two different markets, then equilibrium price in one market helps in determining the equilibrium price in other market with lag. These two markets can be two geographically segmented markets or it can be spot or futures market. When same commodity is traded in geographically segmented markets, we do not use the term price discovery as one geographically segmented market does not help in determining the price of other geographically segmented market. Price differences in the two geographically segmented markets is equal to the difference in transportation costs ... etc.

For price discovery[28], the essential condition is that the two markets must have a long term (co-integrating) relationship. There may be short term deviation between the prices of two markets. However, through arbitrage and reverse arbitrage these two prices will be brought under equilibrium. If there is a disequilibrium between two markets trading same commodity, then either both markets will move towards equilibrium or the price in one market will remain fixed and the price in other market will move towards that fixed price set by other market. We take the latter case. The market that adjust towards other fixed market, is known as satellite market and the market that fixes the price is known as dominant market (Garbede and Silver 1979). Satellite market shows the past prices of dominant market. In other words, satellite

[27] We are considering two markets.
[28] We use the term price discovery in the context of futures and spot market.

market shows the price of dominant market with lag. The lag can be anything; it can be one day, two days, one week, one month... etc.

Suppose market A is dominant and market B is satellite. We say that there is a lead lag relation between market A and market B. Market A leads the market B. In other words, price discovery is taking place in market A.

Also, it may happen sometime that there may be some local (extra) information in market B which may not be available in market A. In that case the market A will reflect the prices of market B with lag. We call now market B as dominant and market A as satellite. Now market B leads market A; and price discovery is taking place in market B.

References

Bahattin, B and Harris,J.H., 2012. “The Role of Speculators in the Crude Oil Futures Markets”, Working Paper*, U.S. Commodity Futures Trading Commission.*

Bhanumurthy, N.R., Dua, P., and Kumawat, L.,2013. “Weather Shocks and Agricultural Commodity Prices”, *Climate Change Economics,* Vol. 4, No. 3.

Booth, G. G. and Ciner, C., 2001. “Linkages among agricultural commodity futures prices: evidence from Tokyo”, *Applied Economics Letters*, 8, 311–3.

Brooks, Chris, 2002. *Introductory Econometrics to Finance*, 1st edition, Cambridge University Press, UK.

Brooks, Chris, 2010. *Introductory Econometrics to Finance*, 2nd edition, Cambridge University Press, UK.

Buguk, C., Hudson, D. and Hudson, T., 2003. “Price Volatility Spillover in Agriculture Markets: An Examination of U.S. Catfish markets”, *Journal of Agricultural and Resource Economics*, Vol.28, pp.86-99.

Dickey, D.A and W.A Fuller, 1981. “Likelihood Ratio for Autoregressive Time Series with a Unit Root”, *Econometrica*, Vol.49, pp. 1057-1072.

Edwards R. Franklin, Ma W. Cindy, 1992. *Futures and Options*, McGraw-Hill, Inc., USA.

Enders, W., 2010. *Applied Econometric Time Series*, 3rd Edition, Wiley, USA.

Engle, R.F and Granger, C.W.J, 1987. "Co-integration and Error Correction: Representation, Estimation and Testing", *Econometrica*, Vol. 55, pp. 251-276.

Fortenbery, T.R. and Zapata, H.O., 1996. "Stochastic Interest Rate and Price Discovery in Selected Commodity Markets", *Review of Agricultural Economics*, Vol. 65, pp. 645-54.

Fu, L.Q. and Qing, Z.J., 2006. "Price Discovery and Volatility Spillovers: Evidence from Chinese Spot-Future Markets". *Journal of Future Markets*, Vol.23. pp. 1019-1046.

Garbade, K. D., & Silber, W. L., 1983. Price Movement and Price Discovery in Futures and Cash Markets. Review of Economics and Statistics, 65, 289 – 297.

Garbade, K.D., and Silver, W.L., 1979, "Dominant Satellite Relationship between Live Cattle Cash and Future Markets", *The Journal of Future Markets*, Vol.10, pp. 123-136.

Gemen, Heluette, 2005. *Commodities and Commodity derivatives*, Wiley, USA.

Government of India, 2000. **"***National agricultural policy*". New Delhi: Ministry of agriculture.

Government of India, 2001. "*The expert committee on strengthening and developing of agricultural marketing*". New Delhi: Ministry of agriculture.

Government of India, 2008. "*The expert committee to study the impact if futures trading on agricultural commodity prices*". New Delhi: Ministry of Consumer Affairs, Food & Public Distribution.

Granger, C.,1989. *Forecasting in Business and Economics*, 2nd Edition, Academic Press, San Diego.

Gupta, K. and Balwinder, S., 2006. "Price Discovery and Causality in Spot and Futures Markets in India", *The ICFAI Journal of Derivatives Market*, Vol.3, pp. 30-41.

Hernadez, M and Torero, M, 2010. Examining the Dynamic Relationship between Spot and Futures Prices of Agricultural Commodities. *IFPRI Discussion Paper* 00988.

Hiemstra, C., & Jones, J. D., 1994. "Testing for Linear and Non-Linear Granger Causality in the Stock Price-Volume Relation". *Journal of Finance*, 49, 1639 – 1664.

Hoffman, G.H., 1931. "Factors Affecting Prices in Organised Commodity Market", *Annals of the American Academy of Political and Social Science,* Vol. 155, pp. 91-99.

Johansen, S., 1988. "A Statistical Analysis of Co-integration Vector", *Journal of Economics Dynamics and Control*, Vol.12, pp. 231-254.

Kawaller, I. G., Koch, P. D., and Koch, T.W., 1988. "The Relationship between the S&P 500 Index and the S&P 500 Index Futures Prices". *Federal Reserve Bank of Atlanta Economic Review,* 73 (3), 2–10.

Koutmos, G., and Booth, G.G., 1995. "Asymmetric Volatility Transmission in International Stock Markets", *Journal of International Money and Finance*, Vol. 14, pp. 747-762.

Kumar, Sunil, 2004. "Price Discovery and Market Efficiency: Evidence from Agricultural Futures Commodities", *South Asian Journal of Management*, Vol.11, pp. 32-47.

Lake, Fred, 1978. "The Miller's Use of the Commodity Exchange," in A. Peck (Ed.), Views from the Trade. Board of Trade of the City of Chicago, Chicago.

Mahalik,M.K., Acharya D., Babu,M.S., 2010. "Price Discovery and Volatility Spillovers in Futures and Spot Commodity Market: Some Empirical Evidence from India", working" paper *IGIDR*, Mumbai.

Malliaris, A. G. and Urrutia, J. L., 1996. "Linkages between agricultural commodity futures contracts". *Journal of Futures Markets*, 16, 595–609.

Moosa, I. A., and Al-Loughani, N. E., 1995. "The Effectiveness of Arbitrage and Speculation in the Crude Oil Futures Market". *The Journal of Futures Markets*, 15, 167–186.

Moosa,I.A., 2002. “Price Discovery and Risk Transfer in the Crude Oil Futures Market: Some Structural Time Series Evidence”, *Benna Monte del Paschi de Siena Spa*, Vol.31, Blackwell publishers.

Morgan, C.W., 1999. “Futures Market and Spot Price Volatility: A Case Study”, *Journal of Agricultural Economics*, Vol. 50, pp. 247-256.

Morgan, C.W., Rayyner, A.J. and Vaillant, C., 1999. “Policy Arena Agricultural Futures Markets in LDCs: A Policy Response. To Price Volatility?”, *Journal of International Development*. Vol. 11, pp. 893-910.

Newberry, D. M., 1992. Futures markets: Hedging and speculation. In P. Newman, M. Milgate, & J. Eatwell (Eds.), *The new Palgrave dictionary of money and finance* (Volume 2, pp. 207–210), London: Macmillan.

Phillips,P.C and P. Perron, 1988. “Testing for a Unit Root in Time Series Regression”, *Biometrica*, Vol.75, pp. 335-346.

Praveen, D.G., and Sudhakara, A., 2006. “Price Discovery and Causality in the Indian Derivative Market”, *The ICFAI Journal of Derivative Market*, Vol.3, pp. 22-29.

Quan, J., 1992. “Two Step Testing Procedure for Price Discovery Role of Futures Prices”. *The Journal of Futures Markets*, 12, 139–149.

Schwartz, Eduardo S., 1997. The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging, *Journal of Finance*, 52, 923–973.

Schwarz, T. V., and Szakmary, A. C., 1994. Price Discovery in Petroleum Markets: Arbitrage, cointegration, and the Time Interval of Analysis. *The Journal of Futures Markets,* 14, 147–167.

Sehgal, S., Ahmad, W. and Deisting F., 2014. “An Empirical Examination of the Process of Information transmission in India’s Agriculture Futures Markets”, *Journal of Quantitative Economics*, Vol. 12, No.1, January 2014.

Shihabudheen, M.T. and Padhi, Puja, 2010. “Price Discovery and Volatility Spillover Effect in Indian Commodity Market, *Indian Journal of Agricultural Economics*, Vol.65, pp.101-117.

Thomas, S and Karande, K., 2001. “Price Discovery Across Multiple Spot and Futures Markets”,*IGIDR,Mumbai,http://www.igidr.ac.in/~susant/pdfdocs/thomas2001_pricediscovery_castor.pdf*

Tse, Y., 1999. “Price Discovery and Volatility Spillovers in the DJIA Index and Futures Markets”, *Journal of future Markets*, Vol.29, pp. 911-930.

Von Braun, J., and Torero M., 2008. “Physical and Virtual Global food reserves to protect the poor and prevent market failure.*”* *IFPRI Policy Brief* 4 (June), Washington, D.C

Von Braun, J., and Torero M., 2009. “Implementing Physical and Virtual Food Reserves to Protect the Poor and Prevent Market Failure”. *IFPRI Policy Brief* 10 (February). Washington, D.C.

Working, H., 1948. "Theory of the Inverse Carrying Charge in Futures Markets," Journal of Farm Economics 3.

Yatchew, A. 1997. “An Elementary Estimator of the Partial Linear Model”. *Economic Letters* 57: 135–143.

Yatchew, A., 1998. “Nonparametric Regression Techniques in Economics”. *Journal of Economic Literature* 36: 669–721.

Yatchew, A., 2003. *Semiparametric Regression for the Applied Econometrician*. Cambridge: Cambridge University Press, UK.

Zapata,H., Fortenbery, T.R. and Armstrong, D., 2005. ‘Price Discovery in the World Sugar Futures and Cash Markets: Implications for the Dominican Republic’, Staff Working Paper, Agricultural and Applied Economics, No.469.

Zhong, M., Darrat, A.F., and Otero,R., 2004. “Price Discovery and Market Efficiency: Evidence from Agricultural Futures Commodities”, *South Asian Journal of Management*, Vol.11, pp.52-56