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Price discovery and arbitrage linkage in the Indian agricultural commodity futures market: a study of gram futures

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Abstract This study has attempted to empirically examine the price discovery function of futures market and arbitrage linkage between spot and futures markets for gram. The main findings are that (i) the futures market plays a leading role in price discovery but the spot market cannot be considered as a pure satellite, (ii) there is an impact of seasonality as the futures and spot prices are not co-integrated for the lean season contract, and (iii) the arbitrage linkage between spot and futures markets is weak.

Keywords Commodity futures, Arbitrage, Price discovery, Gram, India

JEL classification G10, G13, G18

1 Introduction

The process of economic liberalization initiated in 1991 has led to significant fluctuations in prices of agricultural commodities in India. In order to manage the price volatility, the Government of India has been encouraging commodity futures that provide for payment against delivery at a future date as against immediate payment against delivery of goods in the case of spot market. The spot markets for agricultural commodities are often characterized by the presence of physical markets usually located nearer to the production center and are regulated by state legislations. Agricultural spot markets are more regional, fragmented and dominated by physical market players such as farmers, traders and processors. The commodity futures markets operate on the electronic platform provided by the commodity futures exchanges with pan-India outreach and their participants include speculators and hedgers who are mostly the value chain participants and arbitrageurs. The price movements in the commodity spot and futures market are linked by arbitrage. The difference between the futures and spot price is due to storage and interest cost minus the convenience yield. This difference is referred to as the basis. Futures prices are usually higher than the spot prices and this phenomenon is known as “contango”. However, the futures market is said to be in “backwardation” when the spot prices rule higher than the futures prices. This happens during the lean season, when the commodity supply and inventory in the spot market are very low, leading to a rise in the convenience yield.

The commodity futures market performs the functions of price discovery and price risk management. It is expected to provide price signals to farmers at the time of sowing, helping them to plan their acreage under crops, and thus manage price risk. This also helps processors to hedge price risk arising out of fluctuations in input prices. Thus, futures market has an important role in providing reliable price signals and price risk management services to the stakeholders in the value chain. This becomes even more important in the context of reforms in agricultural markets aimed to ensure better prices for farmers. The commodity futures market has the potential to insulate them from price volatility, thereby guaranteeing remunerative prices and higher incomes.

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In this background, it is relevant to study if the commodity futures market in India serves the purpose of providing reliable price signals. This question is pertinent as the Government of India provided for setting up of nation-wide, multi-commodity, electronic exchanges in 2003. The main objectives of this paper are to (i) know whether it is the spot or futures market that dominates price discovery, and (ii) assess the arbitrage linkage between spot and futures market.

In this paper, we deal with a storable commodity, gram, and analyze arbitrage linkages following the model of storage developed by Garbade and Silber (1983). Gram has been selected, as India is the largest producer, importer and consumer of gram. Gram accounts for almost half of the total pulses produced in the country. Moreover, gram is one of the leading agricultural commodities traded in commodity futures market. The futures market trade volume for gram reached a peak (1156 lakh tonnes) in 2005-06. However, on account of inflationary concerns, the futures trade in gram was suspended from May to December, 2008. The peak volume during the post-suspension period stood at 849 lakh tonnes in 2011-12. Thus, the trade volumes could never fully recover from the impact of suspension.

The empirical research on commodity futures market has explored its ability to discover future prices and lead the spot market. The evidence is mixed, depending on the commodity in question (Asche & Guttormsen 2001; Holly Wang & BingfanKe 2002; McKenzie & Holt 2002; Naik & Jain 2002; Chopra & Bessler 2005; Karande 2006; Sahi & Raizada 2006; Sahoo & Kumar 2009; Mahalik et al. 2009; Iyer & Pillai 2010; Shihabudeen & Padhi 2010; Srinivasan & Ibrahim 2012; Agarwal et al. 2014). Shihabudeen & Padhi (2010) have reported inability of futures market in sugar to discover futures prices. Iyer and Pillai (2010) and Agarwal et al. (2014) point out that the futures market does perform the function of price discovery, despite variations in performance amongst the commodities. In the case of wheat, Sahi & Raizada (2006) conclude that futures prices are not an unbiased predictor of spot prices. Yang et al. (2001) report futures prices as an unbiased estimate of spot prices in the long run for storable commodities. Most of these studies have not accounted for the impact of lean and harvest seasons that are critical to price formation in the case of agricultural commodities, and these have not considered the arbitrage linkage that plays an important role in price discovery and price risk management.

Our results show that gram futures market does perform the function of price discovery but there is a lack of co-integration for the lean season contract, one-year time horizon and poor arbitrage linkage. By assessing the impact of seasonality, it contributes to the empirical literature on price discovery.

Rest of this paper is organized as follows: Section 2 explains data source and descriptive statistics. Section 3 elaborates empirical framework used for price discovery and arbitrage linkage between the spot and futures markets. Section 4 reports the results for price discovery and arbitrage linkage and discusses the same. Section 5 provides the summary.

2 Data and descriptive statistics

The paper uses data on daily futures and spot prices for the near-month futures contract in gram from the database of NCDEX for the period from April 12, 2004 to May 11, 2016. The near-month futures contract is considered because it is the contract closest to the expiry and is the most liquid. The daily futures and spot prices for April (harvest season) and August (lean season) contracts for the period January 21, 2005 to April 20, 2016; and from May 21, 2005 to July 28, 2016 respectively have been considered to examine if the seasonality has an impact on price discovery. It may be noted that futures trading in gram was suspended from May 8, 2008 to December 3, 2008, and this period was not considered for estimation.

The descriptive statistics are provided in Tables A1-A2. The futures and spot returns for the pre and post-suspension period have mean close to zero and the futures returns are more volatile than the spot returns. Further, in the April contract, both the means of spot and futures returns are closer to zero. The spot returns are more volatile than futures returns. This may be because the contract expires during the arrival season and the trading takes place during the sowing season. Similarly, in the August contract, the means of spot and futures returns are closer to zero. However, the futures returns are more volatile than spot returns. This may be because the contract expires during the lean season, whereas the trading in the contract takes place during the harvest season when the spot prices are relatively less volatile.

3 Empirical framework

There are two views about the relationship between commodity futures price and spot price. One, the theory of storage that highlights the storage facilitation role of futures market, and the other relates to its forward pricing role (Fama & French 1987). The theory of storage explains the difference between contemporaneous spot and futures price in terms of interest forgone in storing a commodity, warehousing costs, and a convenience yield on holding inventory. The alternative view splits futures price into an expected risk premium and a forecast of the future spot price (Fama & French 1987).

The storage facilitation role is considered important for price discovery because the arbitrage function works through storage. This line of study is associated with the cost-of-carry model, which provides the framework for modeling the temporal relationship between spot and futures price. The literature indicates that the theory of forecast power and premium is applicable in the case of bulky and perishable commodities that have high storage cost relative to their value. Gram is a storable commodity; hence we consider the theory of storage as an appropriate framework for empirical analysis of price discovery. In particular, we apply the Garbade and Silber (1983) model which is related to the cost of carry relationship between futures and spot prices, and postulates that a strong arbitrage linkage is a pre-requisite for the performance of price discovery.

We also employ the Johansen's co-integration test for determining the long-run equilibrium relationship between spot and futures prices and the Error Correction Model (ECM) to determine the lead-lag relationship between them.

3.1 Garbade and Silber model

Garbade and Silber (1983) have formulated a model of concurrent price changes in a cash market for a commodity and its corresponding futures market. The model considers the impact of arbitrage on 'how the price changes in the two markets are correlated'. It first considers an equilibrium price relationship between the two markets on the assumption of infinite elasticity of supply of arbitrage services and then extends the relationship to a case of finite elasticity of supply of arbitrage.

On the basis of certain assumptions, such as absence of taxes and transaction costs, no restrictions on borrowings, no short sales in the cash market and a flat term structure of interest rates, the model can be written as:

$$F_k = C_k + r \times \tau_k \qquad \ldots(1)$$

where C_k is the natural logarithm of the cash market price of a storable commodity in period "k". F_k is the natural logarithm of the contemporaneous price on a futures contract for that commodity for settlement after a time interval $r \times \tau_k$ and r is the continuously compounded interest rate.

Equation (1) shows that the futures price will be equal to the cash price plus a premium, which reflects the deferred payment on a futures contract. Whenever the condition of infinitely elastic arbitrage is not satisfied, i.e. if $F_k < C_k + r \times \tau_k$, a market participant can earn riskless profit by purchasing a contract in the futures market, short-selling the commodity in the cash market and investing the proceeds in debt securities. However, these assumptions are quite rigid. In case of most of the commodities traded in the futures market, the transaction and storage costs are substantial. Therefore, deviations from the relationship between cash price and futures price will occur in the real world situation. The model defines a cash equivalent futures price, F_k' as $F_k - r \times t_k$. Thus, F_k' is the cash price that would prevail in period 'k', if all assumptions were satisfied. Thus, F_k' is the futures price net of the financing component.

To describe the interaction between cash price and futures price, the model specifies behavior of agents in the market, wherein there are N_c participants who deal only in cash market, N_f participants deal only in futures market and an unspecified number of arbitrageurs who deal in both markets.

Accordingly, the market clearing prices in cash and futures markets can be written as:

$$\begin{pmatrix} C_k \\ F_k' \end{pmatrix} = \begin{pmatrix} 1-a & a \\ b & 1-b \end{pmatrix} \begin{pmatrix} C_{k-1} \\ F_{k-1}' \end{pmatrix} + \begin{pmatrix} U_{c,k} \\ U_{f,k} \end{pmatrix} \qquad \ldots(2)$$

Equation (2) represents a bivariate random walk, which depends on the elasticity of supply of arbitrage services. In case of no arbitrage, which is implied if a = b = 0 in

Equation (2), there will be no price convergence, as the only linkage between the two markets is arbitrage.

However, in the long- run, the markets will become more perfectly integrated. This happens because the deviations between cash price and future prices lead to a process of continuous arbitrage over a period of time, reducing the spread between C_k and F_k'.

The price discovery then can be examined with a model of daily price behavior.

$$\begin{pmatrix} C_t \\ F_t' \end{pmatrix} = \begin{pmatrix} \propto_c \\ \propto_f \end{pmatrix} + \begin{pmatrix} 1-\beta_c & \beta_c \\ \beta_f & 1-\beta_f \end{pmatrix} \begin{pmatrix} C_{t-1} \\ F_{t-1}' \end{pmatrix} + \begin{pmatrix} e_{c,t} \\ e_{f,t} \end{pmatrix} \quad \ldots(3)$$

Where, C_t is the logarithm of the cash price on day "t" and F_k' is logarithm of the discounted futures price on the same day. β_c and β_f are greater than or equal to 0. The constant terms $\propto_c$ and $\propto_f$ have been added to reflect any secular price trends in the data and any persistent differences between cash prices and futures prices that can be attributed to different conventions for quoting prices.

Identification of the coefficients β_c and β_f implies that

$\beta = \beta_c/\beta_c + \beta_f = a/a + b$

If this ratio is equal to one, so that $\beta_f = 0$, cash and futures prices converge because the cash price always moves towards the futures prices. This is because $\beta_f = 0$ in equation (3) implies that the futures price does not respond at all to previous period's spot price. In such an extreme case, the cash market is considered as a "pure satellite" of the futures market. If this ratio = 0, so that $\beta_c = 0$, then it is the futures price that always makes the adjustment and futures market is a pure satellite. Thus, the values that lie between 0 and 1 imply mutual adjustments and feedback effect between cash and futures market. Thus, equation (3) is considered for the analysis of price discovery.

To examine the risk-transfer function of the futures markets, the equation (3) is solved as follows:

$$F_t' - C_t = \alpha + \delta\,(F_{t-1}' - C_{t-1}) + e_t \quad \ldots(4)$$

The slope, δ can be interpreted as the inverse measure of the elasticity of supply of arbitrage services.

In the context of equation (4), δ measures the rate at which cash and futures prices converge over daily intervals. If δ is small, prices will converge quickly because only a small fraction of the price difference on day t - 1 will persist to day t.

To sum up, the model derives and interprets two parameters. The parameter δ measures (the inverse of) the elasticity of supply of arbitrage services. The parameter β measures the relative dominance of the futures market compared to the cash market in the price discovery process.

3.2 Co-integration and error correction model

3.2.1 Johansen's co-integration test

The starting point is a Vector Auto Regression (VAR) model with 'k' lags constructed from a set of 'g' variables (g ≥ 2), that are integrated of order one, i.e. I (1) and which may be co-integrated.

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots \ldots + \beta_k y_{t-k} + u_t \quad \ldots(5)$$

All variables are (g×1) and coefficients are (g × g)

In order to use the Johansen test, the VAR is turned into a vector error correction model (VECM) of the form

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \ldots \ldots + \Gamma_{k-1} \Delta y_{t-(k-1)} + u_t \quad \ldots(6)$$

$$\Pi = \left(\sum_i \beta_i\right) - I_g$$

$$\Gamma_i = \left(\sum_j \beta_j\right) - I_g$$

(i=1..k & j=1..i)

The test for co-integration between the 'y' variables is calculated by looking at the rank of the Π matrix via its eigenvalues. The rank of a matrix is equal to the number of its characteristic roots (eigenvalues) that are different from zero. The eigenvalues, denoted by λ_i are put in ascending order.

3.2.2 Error correction model

Co-integration implies that each series can be represented by an ECM, which includes last period's equilibrium error and lagged values of first difference of each variable. The primary purpose of estimating ECM is to implement price leadership test between futures price and spot price and it incorporates the long run equilibrium between spot and futures market. In addition, the model shows not only the degree of disequilibrium from one period that is corrected in the next, but also the relative magnitude of adjustment that occurs in both markets in achieving equilibrium. Temporal causality is assessed by examination of the statistical significance and relative magnitude of the error correction coefficients and coefficients on lagged variables. The ECM is given by equations (7) and (8)

$$\Delta F_t = \delta_f + \alpha_f u_{t-1} + \beta_f \Delta S_{t-1} + \gamma_f \Delta F_{t-1} + e_{f,t} \quad \ldots(7)$$

$$\Delta S_t = \delta_s + \alpha_s u_{t-1} + \beta_s \Delta F_{t-1} + \gamma_s \Delta S_{t-1} + e_{s,t} \quad \ldots(8)$$

4 Results

4.1.1 Unit root test

In order to determine the order of integration of futures and spot price, we perform the Augmented Dickey Fuller (ADF) unit root test on the level of futures and spot price. The critical value at the 5% level of significance is 2.86 for both spot and futures prices. The statement of null hypothesis for the ADF unit root test is that there is no unit root. The results are tabulated in Table 1.

Table 1. Unit root results for gram

Period	Series	Values at 5% level of significance
Pre-suspension	Futures	1.83
	Spot	1.57
Post-suspension	Futures	0.25
	Spot	0.17
April contract	Futures	0.25
	Spot	0.78
August contract	Futures	1.78
	Spot	2.19

From the table above, we observe that the null of no unit root cannot be rejected and hence, we conclude that the futures and spot price series are not stationary at levels. However, we perform the test at first differences as well. The tests confirm that the first difference of both futures and spot price is stationary i.e., I (1), and it is stationary at trend and intercept and trend as well**.** The results are the same for all the financial years during the sample period.

4.1.2 Co-integration test

The results of co-integration test using the Johansen technique are shown in Table 2. In this table, *r* denotes

Table 2. Co-integration test results

Period	Null	Values at 5% level of significance
Pre-suspension	r =0	37.45
	r ≤ 1	2.22
Post-suspension	r =0	67.20
	r ≤ 1	0.02
April contract	r = 0	15.21
	r ≤ 1	0.02
August contract	r = 0	25.30
	r ≤ 1	5.64

the number of co-integrating vectors. Since we are considering only two series, the number of co-integrating vectors can be at most one. The critical value at the 5% level of significance for $r = 0$ and $r \leq 1$ is 14.26 and 3.84 respectively. For two series to be co-integrated, the test statistic for $r = 0$ should be significant jointly with an insignificant test statistic for $r \leq 1$.

From Table 2, we observe that futures and spot market prices are mostly co-integrated except for the August contract for which there is no co-integration between futures and spot prices. The co-integration test of futures and spot prices is also performed for each of the financial years during the sample period. It is observed that there is no co-integration for all the years except for 2009-10 and 2012-13. Therefore, the empirical analysis for price discovery is performed for the following periods during which co-integration has been found between spot and futures prices: 2004-05 to 2005-06, 2006-07 to 2007-08, 2009-10, 2010-11 to 2011-12, 2012-13 and 2013-14 to 2015-16.

4.1.3 Price discovery with co-integration and ECM

The results for the pre-suspension period, post suspension period and April contract are provided in Table 3. Table A3 provides the results for the financial years during the sample period during which there was presence of co-integration. We have used only one lag, as it was found to be sufficient in removing autocorrelation. The Durbin Watson test statistic is close to 2 in all the cases, indicating absence of first order autocorrelation.

The results of the error correction model are consistent with and support the results of co-integration test. At

Table 3. Results of ECM

Co-efficient	Pre-suspension	Post-suspension	April contract
$\propto_f$	-0.06 (3.518)*	-0.07(5.28)*	0.00(0.14)
β_f	0.028(0.7394)	0.03(1.17)	0.00(0.29)
γ_f	0.005(0.1622)	0.049(1.83)	0.00(0.29)
α_s	0.04(2.926)*	0.02(2.147)*	0.019(2.79)*
β_s	0.34(12.818)*	0.44(20.53)*	0.36(7.90)*
γ_s	-0.09(3.13)	-0.18(7.78)*	-0.08(2.58)*

*Significance at 5% level

least one error correction coefficient is significant in all cases where the Johansen technique indicates the presence of a co-integrating vector. The coefficient β_s is always significant indicating that the causality exists from futures to spot. In other words, price discovery occurs in futures market for the April contract and both the periods.

During the pre-suspension and post-suspension period**,** it is observed that the futures market is dominant in the process of price discovery**.** In case of the April Contract, it is observed that the futures market plays a dominant role. Since it is the harvest season contract, it was expected that the spot market may lead to price discovery. However, the results show that it is the futures market that leads the spot market in price discovery. This implies that the futures market is the leader with respect to forecasting the future trends of spot prices. The results for the financial years of the sample period show that the futures market dominates the spot market. This result is in conformity with the results for the pre-suspension and post-suspension period and the April contract. However, it is observed that there is a lack of co-integration between the spot and futures prices for individual financial years during the sample period. This implies that for a one-year time horizon, the linkage between the two markets is weak. Therefore, even if price discovery does take place over longer time periods, the linkage between the two markets is weak over a one –year period.

4.1.4 Price discovery: Garbade and Silber model

The equation (3) of daily price behavior is considered for the study of price discovery. The futures and spot prices were taken at levels since both are I (1) and are co-integrated. However, the results are in conformity even when futures and spot price returns are employed, except for the last sub-period. This model is applied for the pre- and post-suspension period, April contract and for the years during the sample period for which there is co-integration. Table 4 gives the results.

The ratio β lies between 0 and 1. This shows that neither the cash nor the futures market is a satellite market. It is observed that for both the pre- and post- suspension period, the futures market dominates the spot market.

The futures market plays a leading role in price discovery for the April contract. The results for the financial years also indicate the dominance of the futures market. These results are in conformity with that of co-integration and ECM analysis. Thus, it can be said that the futures market in gram performs the function of price discovery.

Table 4. Results of Garbade and Silber model

Period	β_f	β_c	$\beta = \frac{\beta_c}{\beta_c + \beta_f}$
Pre-suspension Period	0.05	0.08	0.08/0.13 = 0.62
Post-suspension Period	0.06	0.08	0.08/0.14 = 0.570
April contract	0.0007	0.02	0.02/0.0207 = 0.96
2004-05 to 2005-06	0.04	0.09	0.09/0.13 = 0.69
2006-07 to 2007-08	0.05	0.09	0.09/0.14 = 0.64
2009-10	0.07	0.144	0.144/0.214 = 0.67
2010-11 to 2011-12	0.07	0.08	0.08/0.15 = 0.53
2012-13	0.02	0.14	0.14/0.16= 0.88
2013-14 to 2015-16**	0.07	0.06	0.06/0.13 = 0.46

** VAR model with futures and spot price in returns indicates that the futures market dominates.

4.2 Arbitrage linkage

The risk-transfer function of the futures markets is determined by the strength of the arbitrage linkage between the futures and spot markets. The equation (4) is considered to arrive at the parameter that measures the strength of arbitrage linkage.

The slope, δ in Equation (4) can be interpreted as the inverse measure of the elasticity of supply of arbitrage services. Thus, higher the value of δ, the weaker will be the arbitrage linkage between the markets. The δ measures the rate of convergence of cash and futures prices over daily intervals. If δ is small, prices will converge quickly as only a small fraction of the price difference on day t-1 will persist to day t.

The value of δ is calculated for the pre- and post-suspension periods, April contract, August contract and for all the financial years during the sample period. Table 5 provides the results.

Table 5. Arbitrage results

Period	Value of δ
Pre- suspension	0.87
Post-suspension	0.87
April contract	0.98
August contract	0.92
2004-05	0.85
2005-06	0.88
2006-07	0.83
2007-08	0.87
2009-10	0.81
2010-11	0.85
2011-12	0.86
2012-13	0.83
2013-14	0.87
2014-15	0.85
2015-16	0.90

It is observed that the arbitrage linkage between the futures and spot market is very weak. Similar results were arrived at by Garbade and Silber (1983) for agricultural commodities and high values of δ were reported for gram by Iyer and Pillai (2010). The value of the arbitrage linkage is 0.87 for both the pre and post-suspension period. It lies in the range of 0.90 to 0.98 for both the lean and harvest season contracts, which implies that the arbitrage linkage is weak, regardless of the season during which the contracts expire. The value of arbitrage linkage varies from 0.81 to 0.88 during the financial years of the sample period. These years had witnessed considerable fluctuations in both production and futures trade volumes. This implies that a weak arbitrage linkage may be more structural in nature and not significantly influenced by variations in either trade volumes or output.

5 Conclusions and implications

The futures market dominates the process of price discovery for gram. However, there is lack of co-integration between spot and futures prices for most of the individual financial years of the sample period. This implies a poor linkage between the markets over a one-year time horizon. In the analysis of harvest season (April) contract and lean season (August) contract, we find that there is no co-integration between spot and futures prices for the August contract. The lack of co-integration for the lean season contract implies that seasonal factors may have an impact on price discovery. In April contract, the futures market dominates the price discovery process, despite being a harvest season contract, wherein one expects the spot market to play a more dominant role. This implies that the futures market is in a better position to forecast the future trends in the spot prices. The empirical results show a weak arbitrage linkage between the futures and spot markets, which inhibits the ability of the futures market to offer efficient price risk management services.

The policy interventions suggested for strengthening the arbitrage linkage can be classified into three broad measures, viz. warehousing and market intelligence, participation from value chain participants and institutions and transaction costs.

- There is a need to strengthen the warehousing and assaying infrastructure and put in place a reliable market information system on spot prices and physical market trends. The former will ensure that the threat of delivery will be credible, ensuring the convergence of spot and futures prices and the latter will help in ensuring reliable spot market intelligence. Thus, it will help in fostering greater integration between the spot and futures markets.

- The regulator should encourage participation by not only farmers and farmer producer organizations (FPOs) but also by institutions such as banks and corporates with an exposure to the commodity sector. The participation from such stakeholders and value chain participants will help in bringing more liquidity and expertise, which in turn will help in convergence of spot and futures prices.
- There is also a need to improve the ease of doing business by way of reducing the trade cost. The initiatives of the Government such as Electronic National Agricultural Markets (e-NAM) and implementation of Goods and Services Tax (GST) may also help in integration of fragmented agricultural spot markets and in turn, their integration with the futures market.

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Table A1. Descriptive statistics for the pre- and post- suspension period

	Pre-suspension		Post-suspension	
	Spot returns	Futures returns	Spot returns	Futures returns
Mean	0.0000	0.000491	0.00050	0.00057
Median	0.0000	0.0000	0.00000	0.00043
Max	0.09279	0.07251	0.09234	0.17517
Min	-0.08	-0.14469	-0.0531	-0.1164
Standard deviation	0.01403	0.01645	0.01348	0.015963
Skewness	-0.24700	-1.24823	0.61908	0.487475
Kurtosis	8.24	16.55765	6.899127	13.72977
Jacque Bera	1436.351	9789.169	1455.325	10097.42
Prob	0.000	0.000	0.0000	0.0000

Source: Estimated by authors based on NCDEX database.

Table A2. Descriptive statistics for the April and August expiry contract

	April		August	
	Spot returns	Futures returns	Spot returns	Futures returns
Mean	0.001179	0.000992	0.001538	0.001568
Median	0.000000	0.000000	0.000000	0.000412
Max	0.546011	0.471570	0.226823	0.350480
Min	-0.149722	-0.144886	-0.282717	-0.220103
Std dev	0.025993	0.019759	0.020919	0.026889
Skewness	9.938477	10.33392	0.766953	6.782789
Kurtosis	175.6437	239.6415	55.93773	94.58035
JacqueBera	185617	3472571	150638.8	460332.0
Prob	0.0000	0.0000	0.0000	0.0000

Source: Estimated by authors based on NCDEX database.

Table A3. ECM results for the financial years

Co-efficient	2004-05 to 2005-06	2006-07 to 2007-08	2009-10	2010-11 to 2011-12	2012-13	2013-14 to 2015-16
$\propto_f$	-0.06	-0.04	-0.08	-0.08	-0.01	-0.08
	(2.70)*	(2.00)*	(2.10)*	(2.90)*	(0.53)	(3.84)*
β_f	-0.08	-0.03	0.04	0.07	0.04	0.001
	(1.39)	(0.71)	(0.50)	(1.25)	(0.53)	(0.03)
γ_f	0.10	-0.03	0.05	0.015	-0.03	0.099
	(2.07)*	(0.70)	(0.833)	(0.30)	(0.44)	(2.22)*
α_s	0.03	0.05	0.06	0.006	0.06	0.015
	(1.81)	(2.68)*	(2.33)*	(0.31)	(2.05)*	(0.78)
β_s	0.34	0.32	0.39	0.48	0.428	0.43
	(9.58)*	(8.57)*	(8.77)*	(13.66)*	(8.56)*	(10.77)*
γ_s	-0.11	-0.08	-0.18	-0.09	-0.12	-0.23
	(2.61)*	(1.95)	(3.32)*	(2.29)*	(2.30)*	(5.53)*

*denotes significance at 5% level.