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Price Discovery, Transmission and Volatility : Evidence from Agricultural Commodity Futures[§]

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Abstract

This paper has examined the efficiency of futures trading in wheat, chickpea, maize and barley in terms of price transmission, price discovery and extent of volatility in prices. Wheat and barley have exhibited phenomenal growth coupled with high instability in futures trade quantity and value. Except for barley, futures and spot market prices have been found integrated. However, the level of integration, in terms of price transmission and long-run equilibrium, was most prominent in maize, followed by wheat and chickpea. Price discovery, one of the major benefits of futures trading, and the dominance of futures market in the process of price discovery have been clearly established. The study has indicated that futures are more efficient in price discovery of wheat and maize. Analysis of price volatility has revealed its persistence in spot prices though none of the selected commodities has exhibited an 'explosive' pattern. Further, the study has identified that farmers are not able to participate in the futures market owing to the small-scale production system prevailing in India.

Key words: Futures trading, price discovery, cointegration, price volatility

JEL Classification: C13, C32, G13, G14, M31, M38, Q13

Introduction

Volatility in prices of agricultural commodities has attracted considerable attention in recent years. Price volatility creates uncertainty, which can threaten agricultural performance and has a negative impact on the welfare of farmers (World Bank, 1997). Though various measures are followed to manage price volatility, futures trading is considered to be one of the important options. The futures trading is based on an obligation between a buyer and a seller to fulfil the pre-determined standardized contract entered on the day of agreement for delivery in the future.

Futures contracts perform two important functions, viz. price discovery and risk management (Velmurugan *et al.,* 2010). Price discovery is a continuous process of arriving at a price from the information prevailing in the market. Competitive price discovery is a major economic function and, indeed, a major economic benefit of futures trading. Through this, the available information is continuously transmitted into the futures price, providing a dynamic barometer of supply and demand status (Easwaran and Ramasundaram, 2008). Information flow between spot and futures markets facilitates price fixation of commodity through mutual understanding between the buyer and the seller for which the price has to be paid in the pre-determined time in future. This reduces the chances of very high prices in return for protection against extremely low prices, technically called hedging, i.e. price risk management or risk transfer function.

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Under efficient markets, new information is impounded simultaneously into spot and futures markets when the markets are integrated (Zhong *et al.,* 2004). Alternatively, market integration is a function of how fast and how much information is reflected in prices. The rate at which prices exhibit market information is the speed at which this information is disseminated to the market participants (Zapata *et al.*, 2005). However, in reality, institutional factors such as liquidity, transaction costs, and other market restrictions may produce an empirical lead-lag relationship between price changes in two markets (Brosig *et al.*, 2011). Due to integration, futures markets can incorporate new information more quickly than spot markets given their inherent leverage, low transaction costs, and lack of short sale restrictions (Tse, 1999).

Price stabilization at the times of extreme volatility is another function of commodity futures. But, the issue over the past two decades is that prices of food are more volatile than of any other commodity (Chand, 2010). Escalating prices of food commodities question the sustainability of current economic growth as well as the efficiency of futures trading. Futures trading in rice, wheat, pigeonpea and blackgram was banned in 2007 due to the fear of inflationary pressure. Futures trading in some more commodities, viz. chickpea, potato, rubber and soy oil was banned in 2008, and in sugar in 2009. Listing, delisting and relisting of the commodities on commodity exchanges question the utility of the futures market. The Sen (2008) Committee, constituted to examine the impact of futures trading on food price inflation has observed that the cause and effect relationship between futures and spot prices cannot be established conclusively. The exact impact of futures trading on rising food prices is still under debate (Srinivasan, 2008).

In spite of these, growth in quantity and value of commodities traded in futures markets has shown an increasing trend (Sen, 2008). Despite explicit growth, the active participation of farmers is also important. It helps them to hedge their produce, safeguard from price volatility and also signal the likely prices so that they can decide on their crop choices. In India, where the majority of farmers have low marketed surplus and face problem of price instability, the analysis of futures trading and prescriptions there-from become more relevant to them.

The analysis of efficiency of commodity futures has received much attention from researchers and academicians (Garbade and Silber, 1983; Thomas and Karande, 2001; Sahadevan, 2002; Singh *et al.,* 2005; Easwaran and Ramasundaram, 2008). Though extensive literature on commodity futures is available, most of it focuses on non-agricultural commodities. In India, only a few studies have focused on testing the efficiency of futures trading in agricultural commodities. The present study has analyzed the growth and efficiency of futures trading in selected agricultural commodities and also the extent of volatility in prices due to futures trading.

Data and Methodology

The National Commodity Derivatives Exchange (NCDEX) holds a major share in the agricultural commodity trading in India. The present study is based on the secondary data published by the NCDEX. Four foodgrains (wheat, chickpea, barley and maize) that are traded on NCDEX were selected considering their volume of trade and importance in the food basket. The data on these commodities were collected right from the starting of their trading (Table 1) until 2009-10.

Table 1. Basic information on selected foodgrains traded on NCDEX

Commodity (Binomial name)	Trading symbol	Futures trading started from (dd-mm-yyyy)	Contract size (tonnes)	Trade value (in crore ₹) (July 2009 to June 2010)
Chickpea (*Cicer arietinum*)	CHARJDDEL	12-04-2004	10	116770.90
Wheat (*Triticum aestivum*)	WHTSMQDELI	10-06-2005	10	4027.55
Maize (*Zea mays*)*	MAIZYRNZM	05-01-2005	10	995.13
Barley (*Hordeum vulgare*)	BARLEYJPR	11-12-2006	10	819.01

*Note:** Feed or industrial grade

(i) Market Integration and Price Transmission

Johansen's (1988) multivariate approach was used to examine cointegration of futures market with spot market prices. Before testing for cointegration, the time series of prices was checked for its stationarity. The stationarity properties and unit roots in the time series were substantiated by Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979). This test was conducted on the level and first differences of price series. The time series variables that are integrated, may be of the same order, while the unit root test finds out which variables are integrated of order one, or I(1). The following ADF regression equation was tested for stationarity:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + u_t \qquad \ldots(1)$$

where, Y_t is a vector to be tested for cointegration, t is the time or trend variable, $\Delta Y_t = (Y - Y_{t-1})$ and u_t is a pure white noise error-term. The null hypothesis that, $\delta = 0$; signifying unit root, states that the time series is non-stationary, while the alternative hypothesis, $\delta < 0$, signifies that the time series is stationary, thereby rejecting the null hypothesis.

A cointegrated equation system may be shown as:

$$\Delta Y_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \alpha\beta' Y_{t-k} + \varepsilon_t \qquad \ldots(2)$$

where, Y_t is the price time series, Δ is the first difference operator (Y_t - Y_{t-1}) and matrix $\Pi = \alpha\beta'$ is $(n \times n)$ with rank r $(0 \leq r \leq n)$, which is the number of linear independent cointegration relations in the vector space of matrix. The Johansen's method of cointegrated system is a restricted maximum likelihood method with rank restriction on matrix $\Pi = \alpha\beta'$. The rank of Π can be determined by using λ_{trace} or λ_{max} test statistics. The trace statistics λ_{trace}, is given by Equation (3):

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i), \qquad \text{for } r = 0, 1, \ldots, n\text{-}1 \qquad \ldots(3)$$

where, $\hat{\lambda}_i$s are the Eigen values representing the strength of the correlation between the first difference and the error-correction. Then, the following hypotheses was tested:

H_0: rank of Π = r (null hypothesis), and
H_1: rank of Π > r (alternate hypothesis)

where, 'r' is the number of cointegration equations.

The above test was carried out on the assumption of linear deterministic trend in original data and only intercept in the cointegrating equation. The cointegrating equation has only the intercept (no trend) because of differencing the price series while checking for its stationarity, whereas the original price series follows a trend since the mean and variance are non-constant over a period of time (non-stationary).

After testing for cointegration between futures market and spot market prices, the residuals show deviation from the equilibrium and this equilibrium error in the long-run tends to be zero. Vector error correction model (VECM) was used to capture the deviations from long-run equilibrium (Brosig *et al.*, 2011). Linear deterministic trend model was run only for the cointegrated series across contracts specifying the number of cointegration equations between the spot market and futures market. The model was then tested for the maximum value of log likelihood ratio. The coefficient of error-correction term indicates the speed at which the series returns to equilibrium. If it is less than zero, the series converge to long-run equilibrium and if it is positive and zero, the series diverges from equilibrium.

(ii) Price Discovery

The Garbade and Silber's (GS) approach was used for estimating the efficiency of futures market in terms of price discovery (Thomas and Karande, 2001). The basic structure of model is given by Equation (4):

$$\begin{bmatrix} S_t \\ F_t \end{bmatrix} = \begin{bmatrix} \alpha_s \\ \alpha_f \end{bmatrix} + \begin{bmatrix} 1-\beta_s & \beta_s \\ \beta_f & 1-\beta_f \end{bmatrix} \begin{bmatrix} S_{t-1} \\ F_{t-1} \end{bmatrix} + \begin{bmatrix} e_{s,t} \\ e_{f,t} \end{bmatrix} \qquad \ldots(4)$$

where, S_t is the natural logrithm of daily spot price at the t^{th} period, F_t is the natural logrithm of daily futures price at the t^{th} period, α_s and α_f reflect the constant secular trend in spot and futures markets, respectively and β_s and β_f reflect the influence of lagged price from one market on the current price in the other market. In the GS framework, the estimated equations are given as:

$$S_t - S_{t-1} = \alpha_s + \beta_s (F_{t-1} - S_{t-1}) + e_{s,t} \qquad \ldots(5)$$

$$F_t - F_{t-1} = \alpha_f - \beta_f (F_{t-1} - S_{t-1}) + e_{f,t} \qquad \ldots(6)$$

Here, the explanatory variable (F_t–S_t) forms the 'basis' that is the difference between futures and spot prices. The 'basis' variable should reflect the cost of capital from the trading date till expiry date, and should contain a negative time trend, i.e.

$$F_{t-1} - S_{t-1} = \alpha_b + \beta_b (t-1) + e_{b,t} \quad \ldots(7)$$

The 'basis' was regressed for each contract, on a time variable (t–1), where t was the time to maturity of the futures contract; and it was found that the estimated coefficient on time trend (β_b) had turned negative, as expected. In the GS framework, Equations (5) to (7) were estimated using 'seemingly unrelated regression' (SUR) model. If the estimated coefficient of β_s is significant and β_f is insignificant, the price discovery occurs only in the futures market. This would imply that the spot market is a pure satellite of the futures market and there is a convergence of futures and spot prices because spot prices move towards futures. If β_f is significant and β_s is insignificant, price discovery occurs only in the spot market. If both β_s and β_f are significant, price discovery occurs in both the markets. If $\beta_s > \beta_f$, futures market dominates the spot market, and if $\beta_f > \beta_s$, spot market dominates the futures market. If both β_s and β_f are insignificant, then price discovery occurs in neither market.

(iii) Volatility in Prices of Agricultural Commodities

In order to compute the extent of price volatility in the spot market consequent to futures trading in agricultural commodities, the generalized autoregressive conditional heteroscedasticity (GARCH) model was fitted. Daily historical prices, the best indicator of volatility, were collected for representative spot market of the selected crops and transformed into natural logarithms. The analysis was undertaken for the entire period right from the starting date of futures trading till 31st December, 2010 as well as for the current year in order to have a comparison. The missing observations were adjusted with the previous closing price of daily trading. Before fitting the GARCH model, autoregressive integrated moving average (ARIMA) filtration was done to identify the best fit ARCH term and then GARCH model was fitted (Bollerslev, 1986). The representation of the GARCH (p, q) is given as:

$$Y_{it} = \alpha_0 + b_1 Y_{it-1} + b_2 Y_{it-2} + e_{it} \quad \text{(autoregressive process)} \quad \ldots(8)$$

and the variance of random error is:

$$\sigma^2_{i,t} = \omega + \sum_{i=1}^{p} \beta_i \sigma^2_{t-i} + \sum_{i=1}^{q} \alpha_i \varepsilon^2_{t-i} \quad \ldots(9)$$

where, Y_{it} is the spot price in the t^{th} period of the i^{th} commodity, p is the order of the GARCH term and q is the order of the ARCH term. The sum of ($\alpha_i + \beta_i$) gives the degree of persistence of volatility in the series. The closer is the sum to 1, the greater is the tendency of volatility to persist for a longer time. If the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from the mean value.

Besides above analyses, the usual compound annual growth rate and instability indices were worked out for value and quantity of traded commodities. The extent of instability in futures trading was estimated using coefficient of variation for no-time trend series and Cuddy-Della Valle instability index (Cuddy and Della Valle, 1978) for the series exhibiting a trend.

Results and Discussion

Growth and Instability in Futures Trading of Foodgrains

Futures trading exhibited an impressive growth in terms of number of products offered, participants, spatial distribution and volume of trade since the establishment of the organized commodity exchanges in the country. National Multi Commodity Exchange (NMCE) was the first exchange to be granted permanent recognition by the Government, where futures trading started on 26th November, 2002 in 24 commodities. Subsequently, Multi Commodity Exchange of India (MCX) was established in November 2003 and National Commodity and Derivatives Exchange Limited (NCDEX), the largest agricultural commodity exchange of the country, commenced its operation in December 2003. Now, there are about 25 recognized futures exchanges, including the regional exchanges, with more than 3000 registered members. Trading platforms can be accessed through 20000 terminals spread over 800 towns/cities across the country. Forward Markets Commission (FMC) of the Ministry of Consumer Affairs is the regulator of futures trading in India.

The agricultural commodities led the initial spurt in futures trading, and constituted the largest proportion of the total value of trade till 2005-06 (55.32%), but in 2006-07, their share declined to 10.7%. It was partly due to the imposition of stringent regulations on agricultural commodities and the dampening of sentiments due to suspension of trade in few commodities (Sen, 2008). In the past three years, there has been a revival of commodities futures trading in India, in both number of commodities and volume of trade. Twenty-four agricultural commodities were permitted for trading by the FMC in 2010.

Table 1 presents the basic information on selected foodgrains, viz. trading symbol of the commodity in Indian commodity exchanges, inception date of futures trading, contract quantity and trade value for the agricultural year 2009-2010. Among these commodities, chickpea has its old inception and ranks first in futures trading with a turnover of ₹ 116771 crore, followed by wheat (₹ 4028 crore) and maize (₹ 995 crore). The estimated parameters for traded quantity and value of selected foodgrains are furnished in Table 2. The compound annual growth rate could not be calculated since the date of inception of futures trading due to lot of missing observations (absence of trade).

Futures trade in wheat and maize exhibited a significant positive growth in both quantity and value. A significant decline in value was noticed in chickpea (-3.43%), which might be due to the decline in domestic production and the policy dilemma regarding ban on trading. The instability in futures trade showed very high variation in case of barley, in both quantity (87.81%) and value (94.49%), followed by maize. Instability from the date of inception of trading was highest in the case of wheat (159.68%) and maize (160.25%) in quantity and value terms, respectively. The instability analysis highlights a stable performance of futures trading in India during 2009-2010 compared to the period from the date of futures trading.

Barring wheat and maize, other foodgrains exhibited a positively skewed distribution in quantity and value during 2009-2010. All the commodities showed a platykurtic (fat or short-tailed) probability

Table 2. Estimated parameters for trade quantity of selected commodities and their value of trade in NCDEX

Commodity	Parameter	2009-10		Since inception to 2009-10	
		Quantity	Value	Quantity	Value
Chickpea	CGR (%)	-2.33	-3.43*	—	—
	Instability (%)	21.52^	25.40^	92.86^^	94.32^^
	Skewness	0.26	0.30	1.35	1.35
	Kurtosis	-1.55	-1.38	1.34	1.67
Wheat	CGR (%)	10.02**	10.15**	—	—
	Instability (%)	43.40^	46.48^	159.68^^	155.80^^
	Skewness	-0.31	-0.15	2.81	2.87
	Kurtosis	-1.59	-1.55	8.40	9.28
Maize	CGR (%)	20.32***	20.59***	—	—
	Instability (%)	56.20^	56.97^	154.03^^	160.25^^
	Skewness	-0.59	-0.51	4.16	4.42
	Kurtosis	-1.39	-1.42	22.83	25.52
Barley	CGR (%)	7.98	9.72	—	—
	Instability (%)	87.81^	94.49^	108.29^^	113.48^^
	Skewness	1.04	1.15	2.04	2.33
	Kurtosis	-0.23	0.00	5.42	7.40

Notes: ***, ** and * indicate the significance respectively at 1 per cent, 5 per cent and 10 per cent levels of probability, ^ indicates the coefficient of variation, and ^^ indicates the Cuddy-Della Valle instability index distribution function in 2009-2010; whereas, leptokurtic (slim or long-tailed) pattern of distribution was noticed for the entire period.

Efficiency of Futures Trading in Foodgrains

The efficient performance of agricultural commodities in futures trading has been concluded based on Johansen's multivariate cointegration analysis and GS model. Before testing for cointegration between futures and spot prices, it becomes mandatory to check the order of integration for the level series. Therefore, unit root tests of each variable were conducted at their levels as well as at first differences of non-stationary level variables for each contract (crop-wise) after converting the original series to natural logarithms. Futures contracts are the standardised and pre-determined contracts framed by the exchanges and opened for trade for a delivery date in the future. This mostly coincided with the harvest season of the crops (Table 3).

(a) Price Transmission between Futures Market and Spot Market

The results of the estimated ADF statistics indicated the presence of unit root at their levels, i.e. non-stationarity of both futures and spot price series (Table 4). However, all the non-stationary variables were found to be stationary at their first differences, and therefore, were integrated of order one, I(1). The conformation that each level series is of I(1) allowed to proceed for Johansen's cointegration test. The estimates of the cointegration test are presented in Table 5 along with the coefficient of correlation between futures market and spot market. Correlation coefficient revealed a significant positive co-movement between the futures and spot price series, as expected. The cointegration test revealed the Eigen value and the trace statistic for each set of variables. The test rejected the null hypothesis of no cointegration relationship between the futures and spot prices (r=0) at 5 per cent level of probability, indicating the presence of one cointegration equation between those markets. The purpose of this analysis was to know whether the futures and spot market prices are cointegrated, and thereby price transmission (information flow) takes place, helping in the process of price discovery.

Johansen's cointegration test (Table 5) showed the presence of one cointegration relationship between the futures market and spot market prices of chickpea (5 contracts), wheat (5 contracts) and maize (6 contracts). There was no cointegration between the futures market and spot market prices of barley, indicating inefficiency in its trading probably due to higher transaction cost. Generally, inefficient markets have high transaction cost and prevent price transmission (Brosig *et al*., 2011). In general, the results show efficiency in performance of futures trading, in terms of price transmission, for most of the contracts in foodgrains.

Johansen's test showed there is a long-run equilibrium between spot and futures prices for one or more of the contracts irrespective of commodities, justifying the use of a vector error correction model (VECM) for capturing the short-run dynamics. The application of VECM on foodgrains indicated that most of the estimated coefficients were positive for both futures and spot markets (Table 6). The vector error correction (VEC) coefficient was 0.1407 for futures price and 0.0849 for spot price in case of chickpea (10.09.2009 to 19.02.2010). This indicated that how fast the dependent variables such as spot and futures prices absorb and adjust themselves for the previous period disequilibrium errors. In other words, the VEC coefficient measures the ability of spot and futures prices to incorporate shocks or speculations in the prices. In this case, futures and spot markets absorbed

Table 3. Commodity-wise crop calendar indicating the sowing and harvest periods

Commodity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chickpea		Harvest	Harvest	Harvest						Sowing	Sowing	
Wheat		Harvest	Harvest	Harvest						Sowing	Sowing	Sowing
Maize		Harvest	Harvest	Harvest						Sowing	Sowing	
Barley		Harvest	Harvest	Harvest						Sowing	Sowing	Sowing

Source: India Commodity Year Book (2011), Food and Agriculture Organisation and Handbook of Agriculture (ICAR)

Table 4. Estimated ADF statistics for unit root test of futures and spot price time series

Commodity (Spot market)	Contract period	Futures market price		Spot market price		Order
		Level	1st difference	Level	1st difference	
Chickpea (Delhi)	10.07.09 to 18.12.09	-1.57	-11.94*	-2.13	-9.88*	I (1)
	10.08.09 to 20.01.10	-0.79	-12.72*	-2.23	-10.64*	I (1)
	10.09.09 to 19.02.10	0.23	-10.51*	-1.27	-10.79*	I (1)
	10.10.09 to 19.03.10	0.10	-10.31*	-0.80	-8.86*	I (1)
	10.11.09 to 20.04.10	-0.81	-10.65*	-1.14	-10.41*	I (1)
	10.12.09 to 20.05.10	-1.77	-11.28*	-1.67	-10.23*	I (1)
	11.01.10 to 18.06.10	-1.62	-10.96*	-2.44	-9.69*	I (1)
Wheat (Delhi)	10.09.09 to 20.01.10	-1.69	-10.07*	-1.91	-9.52*	I (1)
	10.09.09 to 19.02.10	-1.95	-11.01*	-2.23	-10.52*	I (1)
	10.09.09 to 19.03.10	-1.62	-12.12*	-1.81	-10.86*	I (1)
	10.10.09 to 20.04.10	-0.65	-12.11*	0.13	-9.01*	I (1)
	10.11.09 to 20.05.10	-1.27	-12.82*	-0.70	-8.98*	I (1)
	10.12.09 to 18.06.10	-1.20	-12.82*	-1.49	-8.98*	I (1)
Maize (Nizamabad)	10.10.09 to 20.11.09	-2.00	-5.18*	-0.89	-5.67*	I (1)
	10.10.09 to 18.12.09	-3.04	-7.97*	-1.01	-7.07*	I (1)
	10.10.09 to 20.01.10	-1.13	-8.27*	-1.05	-8.65*	I (1)
	10.10.09 to 19.02.10	-0.33	-9.97*	-0.06	-10.15*	I (1)
	10.11.09 to 19.03.10	-0.71	-11.43*	0.55	-10.86*	I (1)
	10.12.09 to 20.04.10	-0.88	-9.24*	-2.26	-10.37*	I (1)
	11.01.10 to 20.05.10	-3.45	-8.10*	-1.21	-8.8*	I (1)
	10.02.10 to 18.06.10	0.31	-9.68*	1.68	-8.25*	I (1)
Barley (Jaipur)	10.09.09 to 20.04.10	-1.63	-13.26*	-0.78	-12.19*	I (1)
	10.11.09 to 20.05.10	-1.65	-13.40*	-0.67	-14.89*	I (1)
	10.12.09 to 18.06.10	-1.34	-9.78*	-0.18	-13.45*	I (1)

Note: * indicates the significance at one per cent level of MacKinnon (1996) one-sided p-values

14 per cent and 8 per cent, respectively to move towards equilibrium in the prices. The information flow was more in futures market as is evident from the magnitude of the VEC coefficient (0.1407). In rest of the contracts of chickpea, price adjustment was more in spot market than futures market. Similarly in wheat, information flow was more pronounced in spot market, with the exception of January contract. In case of maize, barring March contract, futures prices adjusted faster than spot prices.

(b) Price Discovery in Futures Trading

Table 7 shows the estimated coefficients from the 'seemingly unrelated regression' (SUR) model in the GS framework fitted for each contract, crop-wise. Of the seven contracts of chickpea, only two were efficient in price discovery, and in these contracts, spot markets dominated the process of price discovery. In the case of wheat, five contracts out of six helped in the process of price discovery and the futures market dominated in the price discovery (3 contracts). This implies that the spot market located at Delhi is a pure satellite of the futures market and there is a convergence of futures and spot prices because spot prices move towards futures prices. Seven contracts out of eight (two contracts exclusively useful in the price discovery of futures market) were useful in the process of price discovery of maize. In barley, price discovery occurred only in the spot market for a single contract, showing the inefficiency of futures trading. For certain contracts,

Table 5. Estimates of Johansen's cointegration test between futures market and spot market

Commodity (Spot market)	Contract period	Correlation^	Lag length criterion		Eigen value	Trace statistic	Null hypothesis	log likelihood
			AIC value	Order of lags				
Chickpea (Delhi)	10.07.09 to 18.12.09	0.64	-12.43	8	0.0420	6.0488	r=0	803.97
					0.0070	0.8556	r ≤ 1	
	10.08.09 to 20.01.10	0.61	-12.58	3	0.0369	5.6494	r=0	807.99
					0.0087	1.0633	r ≤ 1	
	10.09.09 to 19.02.10	0.92	-12.70	2	0.2600	41.6177	r=0***	854.56
					0.0071	0.9614	r ≤ 1	
	10.10.09 to 19.03.10	0.96	-12.71	2	0.1263	17.6325	r=0**	845.78
					0.0007	0.0863	r ≤ 1	
	10.11.09 to 20.04.10	0.96	-13.45	2	0.2152	33.5172	r=0***	862.16
					0.0077	1.0412	r ≤ 1	
	10.12.09 to 20.05.10	0.97	-13.53	2	0.2044	33.7926	r=0***	873.11
					0.0233	3.1595	r ≤ 1	
	11.01.10 to 18.06.10	0.94	-13.70	2	0.1113	16.6086	r=0**	889.84
					0.0126	1.6125	r ≤ 1	
Wheat (Delhi)	10.09.09 to 20.01.10	0.90	-12.77	1	0.1247	16.5746	r=0**	681.79
					0.0273	2.8526	r ≤ 1	
	10.09.09 to 19.02.10	0.83	-12.96	3	0.0532	10.9818	r=0	867.01
					0.0287	3.8136	r ≤ 1	
	10.09.09 to 19.03.10	0.87	-13.02	2	0.0854	16.5488	r=0**	1037.40
					2.3507	3.8415	r ≤ 1	
	10.10.09 to 20.04.10	0.76	-13.39	2	0.0863	17.4315	r=0**	1077.63
					0.0185	2.9845	r ≤ 1	
	10.11.09 to 20.05.10	0.75	-13.95	2	0.0673	14.5620	r=0*	1100.27
					0.0234	3.7008	r ≤ 1	
	10.12.09 to 18.06.10	0.53	-14.31	2	0.0482	13.9175	r=0*	1120.62
					0.0396	6.2667	r ≤ 1	
Maize (Nizamabad)	10.10.09 to 20.11.09	0.75	-15.18	1	0.4729	20.0646	r=0**	230.81
					0.0734	2.1330	r ≤ 1	
	10.10.09 to 18.12.09	0.39	-14.99	1	0.2344	16.9946	r=0**	414.70
					0.0465	2.5722	r ≤ 1	
	10.10.09 to 20.01.10	0.52	-14.69	1	0.1004	12.1911	r=0	610.82
					0.0437	3.6211	r ≤ 1	
	10.10.09 to 19.02.10	0.79	-14.68	1	0.1317	17.8511	r=0**	805.79
					0.0209	2.3206	r ≤ 1	
	10.11.09 to 19.03.10	0.91	-14.66	1	0.1210	16.8855	r=0**	795.05
					0.0270	2.9527	r ≤ 1	
	10.12.09 to 20.04.10	0.94	-14.68	1	0.2130	26.2554	r=0**	748.38
					0.0361	3.4952	r ≤ 1	
	11.01.10 to 20.05.10	0.64	-15.21	2	0.1162	13.7124	r=0*	827.31
					0.0034	0.3743	r ≤ 1	
	10.02.10 to 18.06.10	0.88	-15.30	2	0.0327	3.8176	r=0	816.72
					0.0035	0.3617	r ≤ 1	
Barley (Jaipur)	10.09.09 to 20.04.10	0.74	-13.24	3	0.0410	8.2237	r=0	1168.44
					0.0062	1.0641	r ≤ 1	
	10.11.09 to 20.05.10	0.67	-13.49	3	0.0569	9.3349	r=0	1030.44
					0.0057	0.8317	r ≤ 1	
	10.12.09 to 18.06.10	0.89	-13.56	2	0.0537	8.0205	r=0	1028.16
					0.0001	0.0147	r ≤ 1	

Notes: ***, ** and * denote the rejection of null hypothesis at 1 per cent, 5 per cent and 10 per cent levels of significance, respectively. ^indicates the significance of correlation coefficient at 1 per cent level of probability (2 tailed)

Table 6. Estimates of vector error correction model on selected commodities

Commodity (Spot market)	Contract period	Cointegration equation		Vector error correction estimates	
		Constant	Coefficient	Futures price	Spot price
Chickpea (Delhi)	10.09.09 to 19.02.10	9.3190	-2.2057	0.1407	0.0849
			(0.1704)	(0.0340)	(0.0276)
	10.10.09 to 19.03.10	7.7644	-2.0081	0.1439	0.1584
			(0.0911)	(0.0530)	(0.0395)
	10.11.09 to 20.04.10	7.8516	-2.0214	0.1052	0.1654
			(0.0860)	(0.0345)	(0.0280)
	10.12.09 to 20.05.10	6.7297	-1.8790	0.0982	0.1873
			(0.0807)	(0.0418)	(0.0322)
	11.01.10 to 18.06.10	-4.3859	-0.4264	-0.1811	-0.3415
			(0.0471)	(0.0609)	(0.0958)
Wheat (Delhi)	10.09.09 to 20.01.10	-2.7704	-0.6162	-0.1400	0.0806
			(0.0650)	(0.0721)	(0.0719)
	10.09.09 to 19.03.10	-2.2243	-0.6854	-0.0352	0.1148
			(0.0858)	(0.0370)	(0.0375)
	10.10.09 to 20.04.10	-3.5108	-0.4984	0.0066	0.0883
			(0.1093)	(0.0194)	(0.0278)
Maize (Nizamabad)	10.10.09 to 20.11.09	-19.0498	1.7858	-0.1906	0.0088
			(1.3574)	(0.0607)	(0.0382)
	10.10.09 to 18.12.09	-14.5458	1.1194	-0.1108	0.0103
			(0.5226)	(0.0307)	(0.0204)
	10.10.09 to 19.02.10	9.1508	-2.3504	0.0462	0.0319
			(0.4628)	(0.0231)	(0.0099)
	10.11.09 to 19.03.10	5.7894	-1.8590	0.0280	0.0469
			(0.2511)	(0.0278)	(0.0136)
	10.12.09 to 20.04.10	22.7361	-4.3583	0.0502	0.0190
			(0.6540)	(0.0136)	(0.0079)

Note: Figures within the parentheses indicate standard error

price discovery occurred in both markets (bi-directional); the possible reason could be that the harvest occurs during that contract-ending period. On the whole, wheat and maize are efficient in terms of price discovery.

Extent of Price Volatility in Foodgrains due to Futures Trading

The results of GARCH model have indicated that different models of various order fit different crops. The highest GARCH order was found for wheat (2, 1) during 2009-2010 (Table 8). For the entire period (Table 9), the highest order was found for wheat (2, 1) and maize (2, 1). With the exception of maize in 2009-10, the ($\alpha_i + \beta_i$) coefficients for rest of the commodities, irrespective of the study period, were estimated closer to 'one', indicating the persistence of volatility in spot prices of selected foodgrains. The results of GARCH analysis also indicated that volatility in the current day prices depends on volatility in the preceding day prices, which was evident from the significant ARCH-term during 2009-2010.

For the entire period (Table 9), volatility in the current day prices was influenced by the volatility in prices during the preceding two days for chickpea, and in the previous day for rest of the commodities. On

Table 7. Estimated coefficients of seemingly unrelated regression for price discovery of selected commodities

Commodity (Spot market)	Contract period	Estimated coefficients		Price discovery
		Spot (β_s)	Futures (β_f)	
Chickpea	10.07.09 to 18.12.09	0.0075	0.0241	None
(Delhi)	10.08.09 to 20.01.10	-0.0048	0.0089	None
	10.09.09 to 19.02.10	0.0521	0.0550***	Spot
	10.10.09 to 19.03.10	0.0367**	0.0572***	Both
	10.11.09 to 20.04.10	0.0017	-0.0049	None
	10.12.09 to 20.05.10	0.0006	-0.0300	None
	11.01.10 to 18.06.10	0.0148	-0.0110	None
Wheat	10.09.09 to 20.01.10	0.0669**	0.0208	Futures
(Delhi)	10.09.09 to 19.02.10	0.0524**	0.0084	Futures
	10.09.09 to 19.03.10	0.0866***	0.0077	Futures
	10.10.09 to 20.04.10	0.0235	0.0186	None
	10.11.09 to 20.05.10	0.0073	0.0202**	Spot
	10.12.09 to 18.06.10	0.0172*	0.0189**	Both
Maize	10.10.09 to 20.11.09	0.0403	-0.1568**	Spot
(Nizamabad)	10.10.09 to 18.12.09	0.0399**	-0.0246	Futures
	10.10.09 to 20.01.10	0.0324***	0.0739***	Both
	10.10.09 to 19.02.10	0.0172**	0.0408**	Both
	10.11.09 to 19.03.10	0.0127	-0.0065	None
	10.12.09 to 20.04.10	-0.0337***	-0.0127	Futures
	11.01.10 to 20.05.10	-0.0532***	-0.1064***	Both
	10.02.10 to 18.06.10	-0.0519***	-0.0534***	Both
Barley	10.09.09 to 20.04.10	0.0127	0.0121	None
(Jaipur)	10.11.09 to 20.05.10	-0.0114	-0.0450**	Spot
	10.12.09 to 18.06.10	0.0173	-0.0212	None

Note: ***, ** and * indicate the significance respectively at 1 per cent, 5 per cent and 10 per cent levels of probability

comparing price volatilities during both the periods, only a miniscule change was noticed in the value of ($\alpha_i + \beta_i$) coefficient. As expected, none of the series showed an 'explosive' pattern as the value of ($\alpha_i + \beta_i$) had not exceeded one, which infers the usefulness of futures trading. The reason for persistence of volatility in prices of some commodities could be due to the nascent stage of futures market.

Relevance of Futures Trading to Smallholders

The present system of futures trading in India has some limitations with respect to the participation of farmers. The constraints faced by the farmers are: high market margin, conceptual difficulties, cumbersome trading procedures and the larger contract size (Velmurugan *et al.,* 2010). It is evident from Table 10 that barring wheat (14.94 tonnes) in Punjab, in rest of the crops the estimated marketed surplus (average productivity × average operational holdings × marketed surplus ratio) across states is much less than the contract quantity. On the whole, deficit was highest in chickpea (9.18 tonnes), followed by barley (8.44 tonnes), maize (7.46 tonnes) and wheat (7.46 tonnes). This analysis highlights the need for the market regulator to adopt some strategies like reducing the contract size or appointing some agencies to serve as aggregators for collecting the farmers produce and pooling them for ensuring the participation of farmers in the futures market. Table 10 also furnishes the level of aggregation, i.e., the number of farmers whose produce should be

Table 8. Estimates of GARCH model for measuring volatility in prices of foodgrains during 2009-2010

Particulars	Chickpea	Wheat	Maize	Barley
Observations (days)	365	365	365	365
Standard deviation	126.75	117.55	35.90	73.08
Skewness	0.20	0.17	0.29	0.49
Kurtosis	2.04	1.63	2.84	2.49
C.V. (%)	5.52	9.41	3.93	7.89
GARCH estimates				
Constant	3.30E-06	6.95E-06**	9.69E-06**	6.39E-06**
	(1.60)	(5.83)	(7.90)	(4.25)
Estimates of ARCH-term (α_i)				
ε^2_{t-1}	0.05**	0.09**	0.19**	0.10**
	(3.98)	(2.73)	(5.84)	(6.25)
Estimates of GARCH-term (β_i)				
σ^2_{t-1}	0.8885**	0.2271**	0.2882**	0.7579**
	(27.12)	(3.10)	(3.71)	(17.68)
σ^2_{t-2}	—	0.4029**	—	—
		(4.86)		
log likelihood	1139.41	1271.57	1477.69	1241.50
GARCH fit	1, 1	2, 1	1, 1	1,1
$\alpha_i + \beta_i$	0.97	1.00	0.50	0.93

Notes: Figures within the parentheses indicate the calculated z statistic
** and * indicate the significance respectively at 1 per cent and 5 per cent levels of probability

aggregated to meet out the contract size set by the FMC. The number of farmers aggregation ranged from two (maize, barley and wheat) to as high as 32 (chickpea) farmers.

Conclusions and Policy Implications

The high volatility in prices of agricultural commodities is a matter of concern for farmers and policy makers. With futures markets being blamed for food price inflation, the present study has found the efficiency of agricultural commodity futures in terms of price transmission, price discovery and degree of volatility in spot markets. Johansen's maximum likelihood approach has been used to analyse the level of integration between futures and spot markets, Garbade-Silber's framework model has been used to find the extent of price discovery and GARCH model has been employed to measure the extent of volatility in spot prices of foodgrains post futures trading in India.

Cointegration analysis indicates the existence of a long-run co-movement between futures and spot prices for most of the contracts, irrespective of commodities chosen for the study. Several inferences have been drawn from the market integration: Price transmission occurs due to the flow of market information which is a consequence of development in information technologies; the speed of convergence depends on the market regulations and policy changes; and market integration is an indicator of efficient functioning of markets. The relationship between futures market price and spot market price in terms of price discovery has revealed the occurrence of hedging in most of the contracts. In particular, futures market dominates the process of price discovery. The study indicates the efficient performance of futures trading in wheat and maize. The extent of volatility in spot prices due to futures trading, as measured by the coefficients of GARCH model, has indicated the persistence of volatility in spot markets, but not of the explosive type.

Table 9. Estimates of GARCH model commodity-wise from inception of futures trading in India

Particulars	Chickpea	Wheat	Maize	Barley
Observations (days)	2455	2028	2187	1461
Standard deviation	396.88	159.34	183.89	176.58
Skewness	-0.24	-0.13	0.49	0.15
Kurtosis	2.95	2.75	2.64	1.59
C.V. (%)	18.33	14.79	23.72	17.32
		GARCH estimates		
Constant	1.34E-06**	1.38E-06**	7.27E-07**	1.28E-06**
	(5.49)	(7.45)	(-3.97)	(7.33)
		Estimates of ARCH-term (α_i)		
ε^2_{t-1}	0.0291**	0.2128**	0.1426**	0.1500*
	(3.23)	(16.70)	(16.44)	(15.30)
ε^2_{t-2}	0.0301**	—	—	—
	(3.33)			
		Estimates of GARCH-term (β_i)		
σ^2_{t-1}	0.9339**	0.1408**	0.4976**	0.86**
	(192.60)	(7.56)	(6.17)	(116.09)
σ^2_{t-2}	—	0.6655**	0.3604**	—
		(38.12)	(4.92)	
log likelihood	7637.29	6888.67	8366.86	5043.298
GARCH fit	1, 2	2, 1	2, 1	1, 1
$\alpha_i + \beta_i$	0.99	1.02	1.00	1.00

Notes: Figures within the parentheses indicate the calculated z statistic
** and * indicate the significance respectively at 1 per cent and 5 per cent levels of probability

The study suggests some policies for a more focused and pragmatic approach for increasing the system's efficiency and generating benefits for the producer farmers.

- There is a need to hedge farmers' produce by facilitating them to participate in futures trading through some institutional innovations like appointing a central agency (banks, cooperative societies, and producers' union) to aggregate their produce in order to meet the contract size requirement.
- The Government should also directly support farmers by reducing the margin money required to participate in futures market. Margin money can be reduced in those commodities that are efficient in trading so as to attract more participants.
- The market regulator should invest more money in popularising the concept of hedging through futures trading among farmers since they are the ultimate beneficiaries. Awareness among farmers can be created through exploratory training programmes and exposure visits to commodity exchanges.
- Regional exchanges (commodity specific) and warehouses equipped with grading and standardization facilities should be opened in more numbers to facilitate farmers' participation.
- Exclusive market regulator for agricultural commodities which behave quite different from non-agricultural commodities should be established to govern, monitor and regulate the trade.

Table 10. A comparison between marketed surplus and futures contract size at NCDEX

State	Marketed surplus ratio (2008-09)	Average productivity in tonnes/ha (2008-09)	Average operational holding* (ha)	Estimated marketed surplus (tonnes)	Contract quantity (tonnes)	Deficit (tonnes)	Aggregation level of farmers
			Maize				
Andhra Pradesh	97.58	4.87	1.2	5.70	10	-4.30	2
Bihar	87.70	2.68	0.43	1.01	10	-8.99	10
Himachal Pradesh	61.95	2.27	1.04	1.46	10	-8.54	7
Karnataka	93.57	2.83	1.63	4.32	10	-5.68	3
Madhya Pradesh	69.68	1.36	2.02	1.91	10	-8.09	6
Rajasthan	70.89	1.74	3.38	4.17	10	-5.83	3
Uttar Pradesh	70.99	1.50	0.8	0.85	10	-9.15	12
India	85.52	2.41	1.23	2.54	10	-7.46	4
Barley							
Rajasthan	62.13	3.06	3.38	6.43	10	-3.57	2
Uttar Pradesh	32.07	2.17	0.8	0.56	10	-9.44	18
India	53.12	2.39	1.23	1.56	10	-8.44	7
			Chickpea				
Bihar	79.47	0.93	0.43	0.32	10	-9.68	32
Madhya Pradesh	78.12	0.98	2.02	1.55	10	-8.45	7
Rajasthan	72.31	0.78	3.38	1.91	10	-8.09	6
Uttar Pradesh	57.17	1.01	0.8	0.46	10	-9.54	22
India	74.15	0.90	1.23	0.82	10	-9.18	13
			Wheat				
Bihar	65.90	2.04	0.43	0.58	10	-9.42	18
Gujarat	83.86	2.38	2.2	4.39	10	-5.61	3
Haryana	81.11	4.39	2.23	7.94	10	-2.06	2
Himachal Pradesh	41.18	1.52	1.04	0.65	10	-9.35	16
Madhya Pradesh	61.24	1.72	2.02	2.13	10	-7.87	5
Punjab	84.79	4.46	3.95	14.94	10	4.94	-
Rajasthan	53.30	3.18	3.38	5.73	10	-4.27	2
Uttar Pradesh	66.15	3.00	0.8	1.59	10	-8.41	7
India	70.87	2.91	1.23	2.54	10	-7.46	4

Notes: Data compiled from NCDEX, Indiastat and Agmarknet portals
* The average operational holding per farmer was taken as per the 2005-06 Agricultural Census for the above calculation and assumed monocropping

- Commodity exchanges should ensure transparency and simplified procedures in trading so that the process can be made comprehensible to many illiterate farmers of our country.

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