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Weather Shocks, Spot and Futures Agricultural Commodity Prices: An Analysis for India[*#]

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Abstract

We analyze the impact of climate shocks on price formation in spot and futures market for food in India where until the recent introduction of commodity futures markets in 2005, the transmission of these shocks on short-term (spot) price movements was unclear. The existence of a futures market is expected to reduce risk, a major component in agricultural production as well as in price formation. Hitherto, the price discovery mechanism was weak and end price was expected to be different (mostly higher unless if some product prices are administered) from equilibrium price. In addition, this weak mechanism was expected to result in higher price volatility. Though the commodity futures market in India is nascent, we model transmission of weather shocks to future and spot prices using monthly data. Based on cointegration analysis, our results suggest strong cointegration between futures prices (based on MCX AGRI-future index) and spot prices (MCX AGRI-spot index) for commodities traded in futures markets. Our causality and impulse response results show futures prices Granger cause spot prices--a shock in futures prices appears to have an impact on spot prices at least for a five month period with maximum impact with a lag of one month. Changes in rainfall affect both futures and spot prices with different lags. Although there could be other factors that affect the futures prices, after controlling for fuel prices our results clearly show the transmission mechanism of weather shocks to prices. Further, with the help of smooth transition models, the study finds that the bivariate relationship between rainfall and prices of rice, wheat and pulses show some non-linearity with the structural change happening after the introduction of futures market. Also, this relation is found to be much stronger with the introduction futures market.

Key words: Weather shock, spot prices, futures prices, smooth transition models, India

JEL Classification: G14, Q10,E30

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1. Introduction

The macroeconomic and policy effects of climate shocksare especially important in the caseof economies where the agricultural sector is significantly dependent on weather conditions. In these economies, any change in the climate pattern can have large adverse impacts on key macroeconomic fundamentals such as prices (inflation) and growth.

A rise in world food prices in the last ten years has been attributed to a large extent on climate shocks. However, in most of the developing and less developed economies, unlike in well-developed commodity markets, the risk mitigation mechanism is quite weak.This, in turn, raises prices in these economies. In India, weather conditions play a major role in the price and expectations formation mechanism. Historically, abnormal rainfall conditions have had adverseand differential impactsover time on different macroeconomic variables. Empirical analysis on these effects has so far been dealt with rather passively in the framework of mostly annual and a few quarterly models. As the adverse impacts of weather on prices are more intermittent and the transmission mechanism is different from the way existing macro models have addressed this issue, an attempt has been made to analyze the transmission mechanism from weather shocks to prices with a relevant framework that largely falls under financial markets literature.

In India, until the introduction of the commodity futures market in 2005, the transmission of weather shocks on short-term (spot) price movements was not very clear. The price discovery mechanism was quite weak and also the end price was expected to be different (mostly higher unless some product prices were administered) from the equilibrium price. In addition, this weak mechanism was expected to result in higher volatility in the prices. In the wake of a sharp rise in food prices in 2007-08, the Government formed a committee under the chairmanship of AbhijitSen to examine the role of futures market in the scenario of rising spot food prices around that time. The Sen Committee[1], analyzing the high inflation (both in WPI and CPI) around 2007, found that the sharp rise in inflation was due to a 'disproportionate' rise in

[1]http://www.fmc.gov.in/docs/Abhijit%20Sen%20Report.pdf

agricultural prices. The Committee, by studying the inflation levels in 21 agricultural commodities that constituted about98 % of total commodities traded in futures market, concluded that inflation indeed accelerated after the introduction of the futures market. At the same time, it also concluded that this rise was not necessarily due to futures trading.Rather, it may have been a coincidence since the high market prices post futures trading were largely due to a sharp fall in the pre-futures trading market prices. It says, "A part of the acceleration in the post futuresperiod may be due to rebound/recovery of the past trend. The period during which futures' trading has been in operation is too short to discriminate adequately between the effect ofopening up of futures markets and what might simply be the normal cyclical adjustment." Further, it says that "Indian data analysed in this report doesnot show any clear evidence of either reduced or increased volatility of spot prices due tofutures trading." However, as the volumes in the futures market have been increasing tremendously in the recent period and given the fact that the government is increasingly intervening in the futures market as and when the domestic spot market prices increase sharply above the acceptable levels, there is a need to re-look at the issue of spot and future market linkages in the agricultural commodity prices.

In the financial market literature, the relationship between spot and future prices is well researched. The literature largely concludes that there is a strong long-term relationship between these two prices (Fama,1970). As the futures market is supposed to play a role of risk-transfer (between hedgers and producers) as well as price discovery by considering the whole set of information flow, this correlation (and cointegration) between futures and spot prices is expected to hold even in the 'abnormal' period (see Pindyack, 2001, for a detailed discussion on the dynamics of futures and spot markets). In the context of (agricultural) commodity futures and spot market relationship, these abnormal periods are largely due to weather (supply) disturbances that re-set the equilibrium prices on a continuous basis.

With this background, in this paper an attempt has been made to analyse the linkage between weather disturbances and their impact on spot and futures agricultural commodity prices in the

Indian context. Further, the study also tries to analyse the impact of weather on food prices both pre and post introduction of futures market in India in June 2005. In Section 2, we examine the theoretical literature analyzing the relationship between futures and spot pricesand describe an analytical framework that relates rainfall disturbances and the futures market. The next section provides a review of the existing empiricalliterature.In Section 4, the econometric methodology adopted in the study is discussed. Section 5 discusses the empirical results and conclusions follow accordingly.

2. Theoretical Framework

In this section, some of the theoretical underpinnings regarding the price discovery and risk transfer mechanism in the commodity markets are reviewed. The most popular model relating the spot and futures prices of a commodity comes from the theory of storage, proposed by Kaldor (1939) and extended by several authors in various directions. Here we review three such models, namely Garbade& Silber(1983, henceforth GS), Foster (1996) and Figuerolla-Ferretti& Gonzalo (2008), which are relevant in understanding the lead-lag relation between spot and futures prices in India and trying to answer the question as to which prices reflect the new information before the other, thus coming close to the 'true' price.

Garbade& Silber (1983) examined the characteristics of price movements in spot (or cash) and futures markets for storable commodities from the perspective of the functions of risk transfer and price discovery. Risk transfer refers to hedgers using futures contracts to shift price risk to others. Price discovery refers to the use of futures prices for pricing cash market transactions. Thus, the risk transfer would be reflected in the extent of co-movements of futures and spot prices. On the other hand, the essence of the price discovery function of futures markets hinges on whether new information is reflected first in changed futures prices or in changed cash prices. The authors develop a model to analyze whether one market is dominant in terms of information flows and price discovery.

Equilibrium prices with infinitely elastic arbitrage: The authors develop an equilibrium price relationship between the futures and cash market prices. Letting C_k denote thenaturallogarithm of the cash market price of a storable commodity in period k, and F_k denote the natural logarithm of the contemporaneous price on a futures contract for that commodity for settlement after a time interval τ_k, under the assumption of a "perfect market", (which basically means no taxes or transactions costs, no limitations on borrowing, no costs other than financing to storing the commodity[2], no limitations on short sales of the commodity in the cash market and no restrictions on use of the proceeds of any short sales, the authors conclude that the cash and futures markets will be in partial equilibrium if

$$F_k = C_k + r.\tau_k \tag{1}$$

Where r is the continuously compounded yield per unit time, assumed not to vary with maturity. This condition says that the futures price will equal the cash price plus a premium which reflects the deferred payment on a futures contract. The assumptions which lead to duration (1) imply that the supply of arbitrage services will be infinitely elastic whenever that equation is violated.

Equilibrium Prices when the elasticity of supply of arbitrage services is finite: A number of assumptions underlying the derivation of the equation (1) are likely to be modified in the real world. For example, transaction costs and storage costs for a cash commodity are substantial for most commodities traded in futures markets. The elasticity of arbitrage, H will in general be finite whenC_k deviates from F'_k because the arbitrage transactions of buying in the cash market and selling in the futures contract or vice versa are not riskless. The spread between cash and futures prices (called the basis) can also change as a result of heterogeneity in the grade and location of the cheapest deliverable commodity, constraints on warehouse space, and the short-run availability of arbitrage capital. The authors show that under such a situation, the C_k andF'_k will be given by the following equations:

[2] This includes storage costs, spoilage and convenience yield to having physical commodity available for merchandising.

$$C_k = \frac{\left\{1+\frac{H}{N_f.A}\right\}r_k^c + \left\{\frac{H}{N_c.A}\right\}r_k^f}{\left\{1+\frac{H}{N_f.A}+\frac{H}{N_c.A}\right\}} \text{and} F_k' = \frac{\left\{\frac{H}{N_f.A}\right\}r_k^c + \left\{1+\frac{H}{N_c.A}\right\}r_k^f}{\left\{1+\frac{H}{N_f.A}+\frac{H}{N_c.A}\right\}} \quad (2)$$

Where $r_k^c = \frac{1}{N}\sum_{i=1}^{N_c} r_{i,k}$ and $r_k^f = \frac{1}{N}\sum_{j=1}^{N_f} r_{j,k}$ are, respectively the mean reservation prices of the participants in the cash and the futures markets, N_c and N_f are the number of participants in the two markets, and A is the elasticity of demand for the i^{th} participant in the cash market with respect to $(C_k - r_{i,k})$. One can clearly see two extreme cases from the above:

(i) If there is no arbitrage $(H = 0)$, then $C_k = r_k^c$ and $F_k' = r_k^f$, i.e., each market will clear at the mean reservation price of its "own" participants.

(ii) If the supply of arbitrage services is infinitely elastic $(H = \infty)$, then $C_k = F_k' = \frac{\left(N_c.r_k^c + N_f.r_k^f\right)}{N_c + N_f}$, so that both markets will clear at the global mean reservation price. The equality of C_k and F_k' when $H = \infty$ shows that the model of equation (2) converges to equation (1) when the elasticity of supply of arbitrage services is infinite.

To derive the dynamic price relationships, this model must be supplemented with a description of the evolution of reservation prices. The authors assume this reservation price changes to $r_{i,k}$ according to the equation

$$r_{i,k} = C_{k-1} + v_k + w_{i,k} \text{for} i = 1,2, \ldots \ldots \ldots .. N_c \quad (3)$$
$$v_k \sim N(0, Tv^2), w_{i,k} \sim N(0, T\omega^2);$$

The price change $r_k^c - C_{k-1}$ reflects the arrival of new information between period $k-1$ and k which changes the price at which the i^{th} participant is willing to hold the quantity $E_{i,k}$of the commodity.

A similar equation describes the evolution of the reservation price of a participant in the futures markets:

$r_{j,k} = F'_{k-1} + v_k + w_{j,k}$ for $j = 1,2, \ldots \ldots \ldots . . N_f$ (4)

$v_k \sim N(0, Tv^2)$, $w_{i,k} \sim N(0, T\omega^2)$

Equations (7) and (8)imply that the mean reservation price in each market in period k will be

$$r_k^c = C_{k-1} + v_k + w_k^c \qquad (5a)$$

$$r_k^f = F'_{k-1} + v_k + w_k^f \qquad (5b)$$

$$v_k \sim N(0, Tv^2), w_k^c \sim N\left(0, \frac{T\omega^2}{N_c}\right), w_k^f \sim N\left(0, \frac{T\omega^2}{N_f}\right)$$

Substituting these expressions for r_k^c and r_k^f into equation (2) we get the model of simultaneous price dynamics:

$$\begin{bmatrix} C_k \\ F'_k \end{bmatrix} = \begin{bmatrix} 1-a & a \\ b & 1-b \end{bmatrix} \begin{bmatrix} C_{k-1} \\ F'_{k-1} \end{bmatrix} + \begin{bmatrix} u_k^c \\ u_k^f \end{bmatrix} \qquad (6)$$

Where $a = \frac{\frac{H}{N_C.A}}{\left\{1 + \frac{H}{N_C.A} + \frac{H}{N_f.A}\right\}}$ and $b = \frac{\frac{H}{N_f.A}}{\left\{1 + \frac{H}{N_C.A} + \frac{H}{N_f.A}\right\}}$

Equation (6) is a bi-variate random walk whose character depends on the elasticity of supply of arbitrage services H:

(i) At one extreme, if there is no arbitrage (because, e.g., the deliverable commodity cannot be easily located and stored), the spot and futures prices will follow uncoupled random walks. That is, if $H = 0$, then $a = b = 0$ in equation (6) and there will be no tendency for prices in the two markets to come together. The absence of price convergence holds even on the settlement date of the futures contract, because, in this model the only linkage between the two markets is arbitrage. Thus, in this extreme case, the futures contract will be a poor substitute for a cash market position, and prices in one market will have no implications for prices in the other market. This eliminates both the risk transfer and price discovery functions of futures markets.

(ii) At the other extreme, suppose that the supply of arbitrage services is highly elastic. As H grows large, the model for equation (6) converges to

$$\begin{bmatrix} C_k \\ F'_k \end{bmatrix} = \begin{bmatrix} 1-\theta & \theta \\ 1-\theta & \theta \end{bmatrix} \begin{bmatrix} C_{k-1} \\ F'_{k-1} \end{bmatrix} + \begin{bmatrix} u_k^c \\ u_k^f \end{bmatrix} \qquad (7)$$

where $\theta = \frac{N_f}{N_c + N_f}$,

In this case C_k and F'_k will be identical and follow a common random walk. The futures contract will be a perfect substitute for a cash market position and prices will be discovered in both markets simultaneously. In fact, there will be no meaningful distinction between the two markets.

(iii) For intermediate cases ($0 < H < \infty$), prices in the two markets will follow an intertwined random walk. Greater elasticity of supply of arbitrage services (larger H) will have two results. First, unexpected changes in cash and futures prices will be more correlated, i.e., $\frac{\partial \mathrm{cov}[u_k^c, u_k^f]}{\partial H} > 0$, so that prices in the two markets will be less likely to move apart. Second, any price separation which does occur will be eliminated more rapidly, i.e., $\frac{\partial E[|F'_k - C_k||F'_{k-1} - C_{k-1}|]}{\partial H} < 0$. Both these consequences will provide for a more stable basis over time, will enhance the substitutability of futures for cash positions, and will improve the risk transfer function of futures markets. That is, to the extent that lower storage and transaction costs and greater homogeneity of the underlying cash commodity encourage arbitrage activities, the linkages between the two markets will be enhanced, thereby improving the risk transfer functions of futures markets.

A Multi-period Model

This model is extended further to relate prices in period k to those in period $k-n$ where n is a positive number greater than 1. The authors say that when $0 < H < \infty$, the multi period model is

$$\begin{bmatrix} C_k \\ F'_k \end{bmatrix} = \begin{bmatrix} \frac{(b+a(1-a-b))^n}{(a+b)} & \frac{(a-a(1-a-b))^n}{(a+b)} \\ \frac{(b-b(1-a-b))^n}{(a+b)} & \frac{(a+b(1-a-b))^n}{(a+b)} \end{bmatrix} \begin{bmatrix} C_{k-n} \\ F'_{k-n} \end{bmatrix} + \begin{bmatrix} \tilde{u}_k^c \\ \tilde{u}_k^f \end{bmatrix} \qquad (8)$$

As n grows large the model if this equation will converge to the model of equation (7), with Tn replacing T in equation (7). This result shows that even if the supply of arbitrage services is relatively inelastic from the clearing to clearing, over longer intervals the markets will appear more perfectly integrated. This occurs because discrepancies between cash and futures prices encourage continued arbitrage over time, thereby putting sustained pressure on the spread between $C_k$and F'_k. Thus, over longer time horizons, futures markets will offer risk transfer opportunities that might be absent over shorter periods. In other words, the substitutability of futures contracts for cash market positions will improve as a direct function of the horizon over which substitution is contemplated.

Implementing the model

While the notion of price correlation underlies both the risk transfer and price discovery functions of futures markets, the structure of equation (8) permits a more complete examination of questions of whether a futures contract is a good substitute for a cash market position, and whether price changes appear first in the futures market or in the cash market. assuming that there are m periods between the daily observations, equation (8) becomes

$$\begin{bmatrix} C_t \\ F'_t \end{bmatrix} = \begin{bmatrix} \alpha_c \\ \alpha_f \end{bmatrix} + \begin{bmatrix} 1-\beta_c & \beta_c \\ \beta_f & 1-\beta_f \end{bmatrix} \begin{bmatrix} C_{t-1} \\ F'_{t-1} \end{bmatrix} + \begin{bmatrix} e_t^c \\ e_t^f \end{bmatrix} \qquad (9)$$

where$\beta_c = \frac{(a-a(1-a-b))^m}{(a+b)}$ and $\beta_c = \frac{(b-b(1-a-b))^m}{(a+b)}$ both of which can be seen to be non-negative. The constant terms were added to these equations to reflect any secular price trends in the data and any persistent differences between cash prices and futures prices attributable to different quotations conventions.

Foster (1996) extends the work of GS to develop a generalized model of dominance. Foster argues that by suggesting that spot and futures prices will have a common evolution, GS are implicitly suggesting that the spot and futures prices will cointegrate, with that cointegrating process being driven by arbitrage. Thus, the more elastic the supply of arbitrage, the greater will be the expected level of integration of spot and futures markets, so that where arbitrage has an infinite supply, the markets will be perfectly cointegrated. Moreover, this implies a testable market relationship in the case of imperfect markets, since an examination of the cointegrating coefficient will reveal the degree of arbitrage activity holding the markets together. The following is a re-expression of the GS model:

$$\Delta C_t = \alpha_s + \beta_c (F'_{t-1} - C_{t-1}) + \epsilon_t^c \qquad (10a)$$

$$\Delta F'_t = \alpha_f + \beta_f (C_{t-1} - F'_{t-1}) + \epsilon_t^f \qquad (10b)$$

On the other hand, for testing of Granger causality between the first differences of $C_t$and F'_t, the temporal relation between spot and futures prices is estimated using the following regressions:

$$\Delta C_t = a_0 + a_1 \Delta F'_{t-1} + a_2 \Delta C_{t-1} + e_t^c \qquad (11a)$$

$$\Delta F'_t = b_0 + b_1 \Delta C_{t-1} + b_2 \Delta F'_{t-1} + e_t^f \qquad (11b)$$

In the above equation the significance of the parameters a_1 and b_1 indicates the flow of information between the two markets. This model captures the actions of hedgers and speculators adjusting their market portfolios to the arrival of new information. The generalized dominance model (GDM) then may be considered to be an ECM consisting of lagged first differences from the cointegrating market together with a once-lagged error-correction term. This model is given as

$$\Delta C_t = \alpha_0 + \alpha_1 \Delta F'_{t-1} + \alpha_2 \Delta C_{t-1} + \alpha_3 (F'_{t-1} - C_{t-1}) + e_t^c \qquad (12a)$$

$$\Delta F'_t = \beta_0 + \beta_1 \Delta C_{t-1} + \beta_2 \Delta F'_{t-1} + \beta_3 (F'_{t-1} - C_{t-1}) + e_t^f \qquad (12b)$$

From the generalized model in eq. (12), an estimated model is derived (by putting coefficients of own lags to zero in the above equation for efficiency).

Figuerolla-Ferretti and Gonzalo (2008) extend the theoretical model developed by GS further to incorporate convenience yield explicitly, leading in turn to possibility of a cointegrating vector different from $(1, -1)$, unlike the discussion above. Specifically, in the presence of non-zero storage costs (s_t) and convenience yield (y_t), the arbitrage condition becomes (in levels of spot and futures prices)

$$F_t = C_t e^{(r_t + s_t)(T-t)}$$

Taking logs and considering $T - t = 1$, we get

$$f_t = c_t + r_t + s_t$$

Assuming the interest rate and storage costs to be evolving according to the equations

$r_t = \overline{r} + I(0)ands_t = \overline{s} + I(0)$ respectively, it can be rewritten as

$f_t = c_t + \overline{rs} + I(0)$where $\overline{rs} = \overline{r} + \overline{s}$. This implies that c_t and f_t are cointegrated with cointegrating vector $(1, -1)$.Now assuming non-zero convenience yield y_t this relation is modified as

$$f_t + y_t = c_t + r_t + s_t$$

In general the convenience yield is approximated by $y_t = g(c_t, f_t, X_t)$where X_t is a vector containing different variables such as interest rates, storage costs and past convenience yields. The first partial derivative is positive while the second is negative. Approximating the convenience yield as a linear function of spot and futures prices, it can be written as

$$y_t = \gamma_1 c_t - \gamma_2 f_t; \quad \gamma_i \in (0,1)$$

Substituting this into the modified arbitrage condition, we get the following equilibrium condition:

$$c_t = \beta_2 f_t + \beta_3 + I(0)$$

with a cointegrating vector $(1, -\beta_2, -\beta_3)$ where $\beta_2 = \frac{1-\gamma_2}{1-\gamma_1}$ and $\beta_3 = \frac{-\overline{rc}}{1-\gamma_1}$

Proceeding along the lines of GS, the authors derive an ECM representation between the spot and futures prices, but unlike the former, this representation has a nonstandard cointegrating vector. Thus, in the presence of arbitrage, spot and futures prices for a storable commodity will tied together through a cointegrating relation. Further, presence of non-zero convenience yield which is related to these prices can cause the cointegrating vector to be different from the standard$(1, -1)$.

<u>Relationship between rainfall and prices and introduction of futures markets</u>

How far the introduction of futures market helped in absorption of the shocks the spot prices? Has it changed the rainfall-price relationship? In the absence of futures market, spot market is the only market where the information about output emanating from weather would be reflected. However, once futures trading is introduced, it would be expected that the transmission of weather shocks to spot prices would be modified (smoothened), since the weather will affect the futures prices also. Therefore, we also study the effect of introduction of futures trading on the relation between rainfall and spot prices of commodities. This is done in the framework of logistic smooth transition regression (LSTR), with time being the transition variable. The advantage of this approach is that it allows for estimation of regime change point endogenously; and the speed of transition is also estimated within the model. This is done for three commodities: rice, wheat and pulses. The basic relation between the spot prices and rainfall is taken to be one of distributed lag type:

$$C_t = \alpha + \phi(L)R_t + \epsilon_t. \tag{13}$$

and the LSTR model is

$$C_t = [\alpha_1 + \phi_1(L)R_t][1 - F(t^*)] + [\alpha_2 + \phi_2(L)R_t]F(t^*) + \epsilon_t \tag{14}$$

where $F(t^*) = \frac{1}{1+e^{-\gamma(t^*-\mu)}}, t^* = \frac{t}{T},$ (15)

and$T$ is the total sample size.

Thus the effect of rainfall on spot prices is captured by $\phi_1(L)$ prior to regime change and by $\phi_2(L)$ after regime-change. If the value of γ is very large, regime-switch is abrupt, while small values of γ indicate smooth transition between the regimes.

To sum up, the theoretical literature does more or less concludes that both spot and futures prices, irrespective of stock or commodity market, is expected to move towards each other in the medium term. But it is not clear about the direction of causality. Further, the theoretical literature does not provide any framework that analyses the exogenous impact of climate shock on prices.

Weather shocks and agricultural commodity prices in India

As the weather shock is more an exogenous shock, analyzing the impact of this exogenous shock is very important in achieving macroeconomic stability. This is because, any disturbances in the expected rainfall or shock are expected to result in supply disturbances, which are in turn expected to affect the agricultural price formation in the medium term given the demand conditions and also the expectation formation about both price and output. Given the intersectoral linkage, this is expected to have adverse impact on the overall value-addition as well as on the employment and demand conditions. Till now this impact of exogenous shock is largely dealt in annual models as the data on major macro variables are available only at the annual levels. But these models cannot capture the impact of shocks which are expected to have large short term impacts as well (mostly on the expectation formation). At the same time, models based on high frequency data, which is useful to track the short term impacts of exogenous shocks, are less useful for policy purpose as some of the crucial variables such as agricultural output is not available. Ideal option would be integrating both the set of models that helps in capturing both short term and long term impacts.

In the short term, if there is a well-developed commodity futures market, we expect that rainfall shock, through expectations formation, is expected to affect the prices in the futures market in the first stage. As discussed in the theoretical literature, we expect the changes in futures market prices to reflect in the spot prices with a significant lag. In the medium term, this firming up of expected inflation might force the monetary authority to tighten its policy as expected rise in food inflation normally gets generalized with a lag. At the same time, as bad monsoon also result in negative output, given its impact on other sectors one is expected to see overall output to fall, which would be higher than the fall in the agricultural output. India is prone to experiencing such conditions regularly (on an average, once in 4-5 years). Until 2005, i.e., before the introduction of commodity futures trading, the effects of bad monsoons on growth and inflation used to be quite large. In 2002, because of the drought conditions, Indian economy grew at 3.8%, the lowest in the past two decades, but the inflation was largely subdued. This is because, in India, most of the food prices were administered and, hence, all the shock was absorbed by fall in the output. In the post-2005, India had two consecutive years of bad monsoons, and at the same time with the introduction of futures market many of the agricultural prices were determined by the market forces. This time around, the fall in output was not large, but the rise in food inflation was substantial. As many criticized the introduction of futures market a main cause of high food inflation, AbhijitSen Committee was formed to look into this issue.

Although the Sen Committee concluded that there is no such transmission of prices between futures and spot markets, these conclusions are based on the short time series data and correspond to the period when the markets were still in a nascent stage with not much volume and at the same time the government intervention was on a regular basis. In addition, as Sahadevan (2008) concludes, the number of participants with knowledge about the microstructure of the commodity markets were very less, which ultimately resulting in not so efficient outcomes.

In effect, most of the recent literature concludes that there is a weak causal relationship between spot and futures markets for commodities in the India. However, in our view, there is a need for re-examining such relationships more so when the existing results were based on short period information. As the volumes in these markets as well as participants with better market knowledge are increasing, there is a need to re-examine this issue. At the same time, the role of rainfall as one of the determinants of futures prices also needs to be examined. It is also necessary to see what role that introduction of futures market played in absorbing the weather shocks in India, particularly in the food prices. This study attempts to address this issue with the help of monthly data. Before undertaking empirical exercise, in the next section, a summary of the existing studies on the research issue is presented.

3. Review of Empirical Literature

There is a vast literature on the issue of relationship between spot and futures prices in the financial markets. Majority of the studies confirm that there is a strong long run relationship between these markets. However, the studies on commodity markets do not derive such confirmed conclusions on this issue. In India, as such the studies on commodity markets are scanty, although for some commodities such as cardamom, groundnuts, coffee etc., India has a tradition of having futures markets for a long time.

Studies based on specific commodities show that introduction of futures market did have impact on the spot prices (Pavaskar, 1970; Nath&Lingareddy, 2008; Sahadevan, 2008: Singh, 2000). A recent study by Dasgupta et al (2010) show a statistically significant and highly strong impact of commodity futures prices on domestic wholesale prices, even after controlling for other determinants. In addition, all the studies show that introduction of futures market did reduce the volatility of prices in both spot and futures market. In other words, futures markets are found to be efficient in absorbing the exogenous shocks (see the summary of the existing literature in Table 1). However, there is no study that analyses the impact of rainfall disturbances on futures prices and spot prices. This study attempts to fill such a gap in the literature.

Table1. Summary of existing research studies

Study	Objectives	Methodology used	Variables/ time period/country	Conclusions
Pavaskar (1970)	To investigate the effect of futures trading on price variability	Average price range, variance of price range, comparison of actual ranges of short term price fluctuations, distribution of price ranges by their magnitude	Daily price data of groundnut /1951-52 to 1965-66/ India	-Spot prices of groundnut fluctuated less widely in presence of futures trading as compared to its absence. -The second reason is that futures contacts provide hedge against fear of price fluctuations which leads to price stabilisation.
Bhattacharya et al (1986)	To determine causal impact of volatility in futures markets on volatility in cash markets for Government National Mortgage Association (GNMA) securities	Daily volatility measures(VC/VF), ARIMA;	GNMA cash and futures prices (8% and 9% coupon) / Dec 1979 to Dec 1982 / USA	-Futures market volatility causes cash price volatility in the short run.
Edwards (1988)	To check stock index futures cause long run excess volatility.	Four proxies of volatility	S&P500 index, S&P100 index, NYSE composite, Value line index / Daily price movements from 1972 to May1987 /USA Stock Market	-Finds no evidence of long run impact of futures' trading on the stock market.
Antoniou & Holmes (1995)	To examine the impact of trading in the FTSE stock index futures on the spot market.	Simple std deviation comparison between pre & post futures period; GARCH(1,1) and IGARCH.	USM (Unlisted securities market) index, FT-500, FTSE-100 stock index and underlying futures. / Nov -1980 to Oct-1991 Pre-futures pd: 1980-May1984 Post futures pd: May1984-1991 / UK Stock Market	-Onset of futures trading resulted in increased spot price volatility -Futures' trading improves quality & speed of information flowing to spot markets. **-P**ersistence of shocks decreased since the onset of futures trading
Shang-Wu Yu (2001)	To examine the impact of index futures contracts on the volatility of the spot market.	Modified Levene statistic and GARCH(1, 1)-MA(1)	Indices: S&P500(US), FTSE100(UK), GS(France), Nikkei225(Japan), AOS(Australia), HS(Hong Kong) /	Noticeable differences found in the AR process as well as in mean of the conditional volatility process for the periods before and after futures listing.

			500 days before and after the start of stock index futures / U.S., U.K., France, Japan, Australia, Hong Kong	-Mean level of volatility increases and volatility shocks are more quickly reflected in the stock market after stock index futures listing.
Nath&Lingareddy (2008)	To investigate the impact of the introduction of futures trading on spot prices of pulses.	Simple percentages, percentage variations, correlations, regression analysis and Granger causality.	Prices of - Urad, gram, pulses, all-commodities, foodgrain; Comdex(MCX); commodity wise futures volumes; and WPI for all commodities under study (as proxy of spot price data). / January 2001 to August 2007 / India	-Trading in futures had a moderate and clear influence on spot prices, particularly of urad. -Granger causality results- futures trading had a positive and significant causal effect on volatilities in spot prices of urad while the same cannot be established for gram. -There was a volatility spill over from urad to foodgrains.
Sahadevan(2008)	1.To assess the causal effects of mentha oil futures on spot prices	Primary survey in U.P. viz. Moradabad, Rampur, and Barabanki, India	Mentha oil futures traded on MCX and NCDEX, spot market price trends. / 2007 / Uttar Pradesh	-Price discovery in futures has helped strengthen spot market prices -Average export prices have shown substantial improvements after introduction of futures trading
Kumar(2010)	To explore linkages between spot markets (*Mandi*) and online commodity futures markets (*Dabba*).	Ethnographic study: interviews with soybean traders and participants observation.	NCDEX data / 2007 / Soybean market in Dhar (Madhya Pradesh, India)	Mandi traders believe that price of soybean on the NCDEX was a result of speculative activity rather than an interaction of market forces.
Aggarwal(1988)	To examine impact of introduction of stock index futures trading on the volatility of certain market indices.	Simple regressions.	S&P500, DJIA, OTC composite / 1st Oct, 1981 to 30th June, 1987 / USA	-Price and return volatility has decreased in the post futures period while volume volatility has increased -Futures related activity seems to cause higher levels of intraday stock market volatility
Singh(2000)	Investigates the hessian spot price volatility before and after the introduction of futures trading	Figlewisky (1981) measure of volatility;	Hessian & Jute price (Forward market commission, Mumbai) / September 1988-September 1997 / India	-In the post-futures introduction, volatility has gone down -Futures markets perform price discovery and price insurance functions

4. Econometric Methodology

This paper analyses the relationship between the spot and future prices in the Indian commodity markets in a cointegration framework with rainfall index as an exogenous variable. A test for non-stationarity is first conducted followed by tests for cointegration and Granger causality. Generalized variance decompositions and impulse responses are then examined. For testing the nonstationarity, we employ the Dickey-Fuller generalized least squares (DF-GLS) test proposed by Elliot, Rothenberg and Stock (1996).For establishing cointegrating relationship, we use standard method developed by Johansen and Juselius (1990, 1992). Although we are fully aware that one of the requirements for this method is a reasonably long time series, one is left with little option in terms of estimation procedures if the variables are found to be non-stationary. If the variables are cointegrated, an error correction model can be estimated as it captures the short-term dynamics of the variables in the system. These dynamics represent the movements of at least some of the variables in the system in response to a deviation from long-run equilibrium. Movements in these variables ensure that the system returns to the long-run equilibrium. Further, the concept of Granger causality can be tested in the framework of the error correction model. While cointegration gives the long-run relationship between variables and Granger-causality throws light on the predictive ability of other variables, innovation accounting methods that include impulse responses and variance decompositions capture the dynamic relationships between the variables. We estimate both these measures once we find any cointegrating relationship. Below, we explain the methodology in detail.

Cointegration and Granger Causality

Cointegration refers to a long-run equilibrium relationship between nonstationary variables that together yield a stationary linear combination. Although the variables may drift away from the equilibrium for a while, economic forces act in such a way so as to restore equilibrium. The possibility of a cointegrating relationship between the variables is tested using the Johansen and Juselius (1990, 1992) methodology which is described below.

Consider the p-dimensional vector autoregressive model with Gaussian errors:

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + A_0 + \varepsilon_t \tag{16}$$

s

where y_t is an $m \times 1$ vector of I(1) jointly determined variables. The Johansen test assumes that the variables in y_t are I (1). For testing the hypothesis of co integration the model is reformulated in the vector error-correction form (VECM):

$$\Delta y_t = -\Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + A_0 + \varepsilon_t \tag{17}$$

$$\text{where, } \Pi = I_m - \sum_{i=1}^{p} A_i, \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j, \quad i = 1,....., p-1.$$

Here the rank of Π is equal to the number of independent co integrating vectors. If the vector y_t is I(0), Π will be a full rank $m \times m$ matrix. If the elements of vector $y_t$are I(1) and co integrated with rank (Π) = r, then $\Pi = \alpha\beta'$, where α and β are $m \times r$ full column rank matrices and there are $r < m$ linear combinations of y_t. Then β' is the matrix of coefficients of the co integrating vectors and α is the matrix of speed of adjustment coefficients.

Under co-integration, the VECM can then be represented as:

$$\Delta y_t = -\alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + A_0 + \varepsilon_t \tag{18}$$

If there are non-zero co-integrating vectors, then some of the elements of α must also be non-zero to keep the elements of y_t from diverging from equilibrium. The model can easily be extended to include a vector of exogenous I(1) variables.

Johansen and Juselius (1990, 1992) suggest the likelihood ratio test based on the maximum eigenvalue and trace statistics to determine the number of the cointegrating vectors. Since the eigenvalue test has a sharper alternative hypothesis as compared to the trace test, it is used to select the number of cointegrating vectors in this paper.

If the variables are indeed cointegrated, an error correction model can be estimated with the lagged value of the residual from the cointegrating relationship as one of the independent variables (in addition to lagged values of other variables described above), the left-hand side variable being as above. The error correction model captures the short-term dynamics of the variables in the system. These dynamics represent the movements of at least some of the variables in the system in response to a deviation from long-run equilibrium. Movements in these variables ensure that the system returns to the long-run equilibrium.

Granger Causality

The concept of Granger causality can be tested in the framework of the error correction model. The Granger causality approach analyses how much of the current variable y_t can be explained by its own past values and tests whether adding lagged values of other variables can improve its forecasting performance. If adding lagged values of another variable, x_t does not improve the predictive ability of y_t, we say that x_t does not Granger cause y_t. In the error correction framework, Granger-causality can be tested by a joint χ^2 test of the error correction term and the lags of x_t.

While cointegration gives the long-run relationship between variables and Granger-causality throws light on the predictive ability of other variables, innovation accounting methods that include impulse responses and variance decompositions capture the dynamic relationships between the variables. We next examine the variance decompositions.

Variance Decomposition Analysis

Variance decomposition breaks down the variance of the forecast error into components that can be attributed to each of the endogenous variables. Specifically, it provides a breakdown of the variance of the n-step ahead forecast errors of variable i which is accounted for by the innovations in variable j in the VAR. As in the case of the orthogonalized impulse response functions, the orthogonalized forecast error variance decompositions are also not invariant to the ordering of the variables in the VAR. Thus, we use the generalized variance decomposition which considers the proportion of the n-step ahead forecast errors of x_t which is explained by conditioning on the non-orthogonalized shocks but explicitly allows for the contemporaneous correlation between these shocks and the shocks to the other equations in the system.

As opposed to the orthogonalized decompositions, the generalized error variance decompositions can add up to more or less than 100 percent depending on the strength of the covariances between the different errors.

Impulse Response Analysis

The impulse response function traces the effect of a one standard deviation shock to one of the variables on current and future values of all the endogenous variables. A shock to any variable in the system does not only affect that variable directly but is also transmitted to all of the endogenous variables through the dynamic structure of the VAR. This function thus measures the time profile of the effect of shocks on the future states of a dynamical system.

The innovations are, however, usually correlated, so that they have a common component, which cannot be associated with a specific variable. A common method of dealing with this issue is to attribute all of the effect of any common component to the variable that comes first in the VAR system (Sims, 1980; Lutkepohl, 1991). In this approach, the underlying shocks to the VAR model are orthogonalized using the Cholesky decomposition of the variance-covariance matrix of the errors. Thus a new sequence of errors is created with the errors being orthogonal to each other, and contemporaneously uncorrelated with unit standard errors. Therefore the effect of a shock to any one of these orthogonalized errors is unambiguous because it is not correlated with the other orthogonalized errors. The drawback is that these orthogonalized impulse responses, in general, depend on the order of the variables in the VAR.

This problem of the dependence on the ordering of the variables in the VAR is overcome in the generalized impulse response method (see Koop et. al, 1996; Pesaran and Pesaran, 1997; Pesaran and Shin, 1998). The generalized impulse responses are uniquely determined and take into account the historical pattern of correlations observed amongst the different shocks. We therefore use the generalized impulse response method for our analysis.

Smooth Transition Models

In the case of smooth transition models (LSTR), we start by determining the linear specification (14) with 12 lags and retain only the significant ones. This specification is then subjected to test for nonlinearity. This test is based on the following reparameterisation of equation (14):

$$C_t = \alpha_1 + \phi_1(L) + [\alpha_2^* + \phi_2^*(L)R_t]F(t^*) + \epsilon_t \tag{19}$$

It is a well-known fact that under the null hypothesis of no non-linearity, the parameters of $\alpha_2^* + \phi_2^*(L)R_t$ are not identified, and therefore the test for nonlinearity is based on the Taylor-series approximation of $F(t^*)$ in the equation above[3]. Finally, we estimate the model (19). This we apply on three major food commodities namely rice, wheat and pulses.

5. Data and Empirical results

The commodity futures market in India, although introduced in 2005, is still in a nascent stage. The functioning of the market is understood only by a small set of participants, who are hedgers and speculators. The reach of the market to the actual producers could be limited. But at the same time, intervention of the government to control rising spot prices is adversely affecting the growth of the futures market. Keeping these developments, an attempt is made to understand the transmission of weather shocks to future and spot prices in India with the help of monthly data. The data and its sources are presented in Table 2. As MCX is one of the largest commodity exchanges in India (the other being NCDEX), we have taken data from this exchange. The data period is from June 2005 to December 2011. Although daily data are available on the prices, non-availability of daily rainfall data forces us to undertake monthly data for the analysis. For the estimation of smooth transition models, we have used the price information of rice, wheat and pulses for a longer period from January 2000 to December 2011.

[3] See e.g., Terasvirta (1994).

A look at Graph 1 show that daily movements in spot and futures prices of agricultural commodities appear to be highly correlated although there are some deviations when one looks at the monthly graph (Graph 2). The correlation matrix in Table 3 suggests that both spot and future prices are highly correlated with correlation coefficient of 0.99.

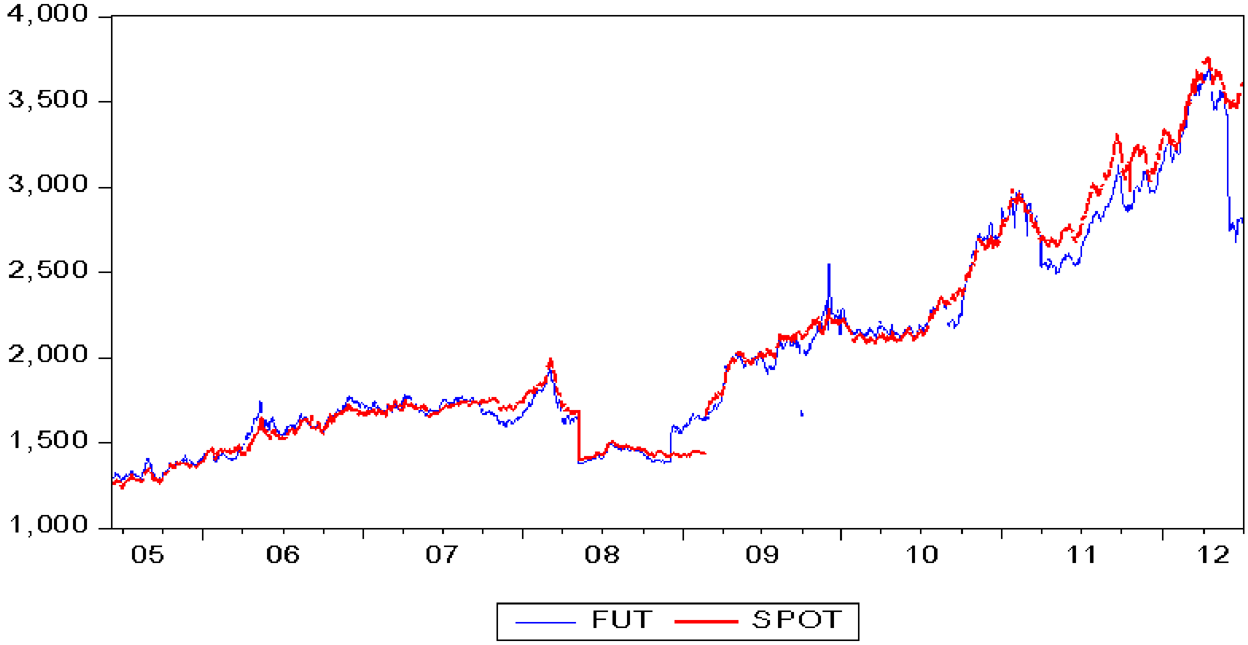
Table 2. Data definitions and sources

Variable	Definition	Period	Source
SPOT	**MCX SPOT-AGRI Index:** AGRI-Spot is a weighted average index of spot prices of following agricultural commodities: Ref. Soy Oil, Potato, Chana, Crude palm oil, Kapaskhalli, Mentha oil, computed by MCX.	June 2005 to December 2011	Multi Commodity Exchange of India Ltd (MCX)
FUT	**MCX FUTURES-AGRI Index:** AGRI-Futures are a weighted average index of the same six agricultural commodities futures traded at MCX.	-do-	-do-
WPIFA	Wholesale price index-FOOD ARTICLES	-do-	Ministry of Commerce and Industry, GOI.
WPIFP	Wholesale price index-FUEL & POWER	-do-	-do-
DSRAIN	Deseasonalized all India Rainfall (upto 1 decimal in mm)	-do-	
RICEP	Price index for Rice	January 2000 to December 2011	CSO
WHEATP	Price index for Wheat	-do-	CSO
PULSEP	Price index for Pulses	-do-	CSO

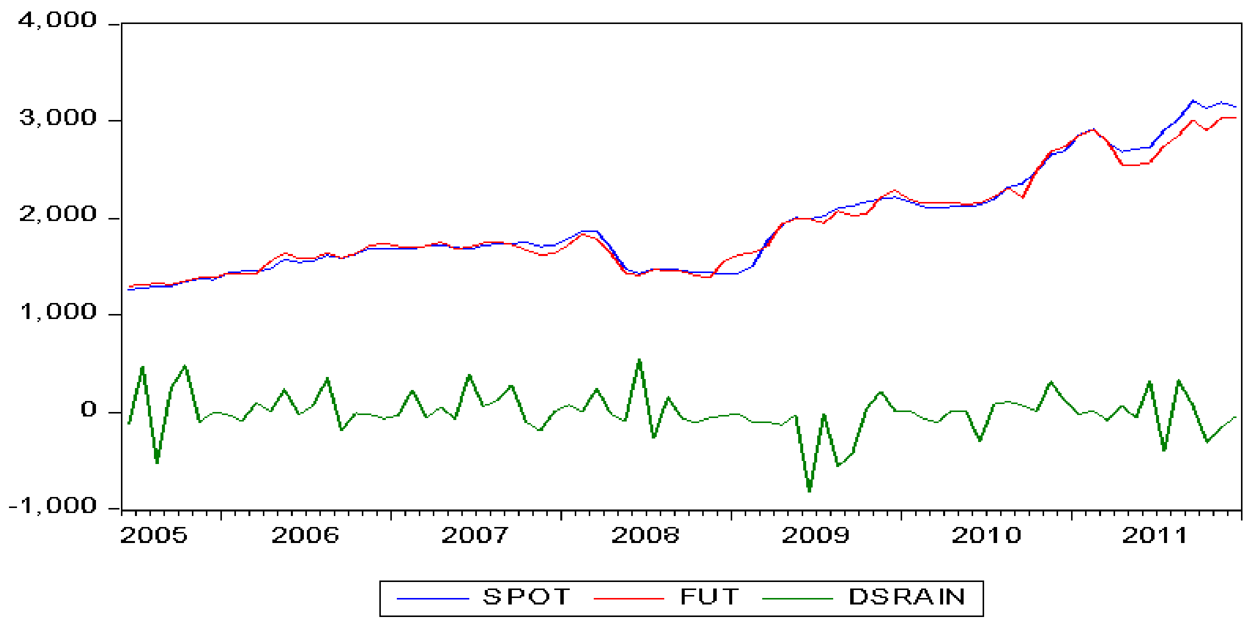
Table 3. Correlation Matrix: June 2005 to December 2011

Variables	SPOT	FUT	WPIFA	WPIFP	DSRAIN
SPOT	1				
FUT	0.992	1			
WPIFA	0.925	0.928	1		
WPIFP	0.866	0.849	0.9228	1	
DSRAIN	-0.084	-0.076	-0.109	-0.0491	1

Graph:1- Daily data on Spot and future market prices (from 6/6/2005 to 30/6/2012)



Graph:2 – Trends in monthly spot and future market prices and rainfall index



We also examine the correlation between the spot/future prices of commodities with the wholesale price index for food articles (WPIFA) within the WPI basket as well as the price index of fuel group (WPIFP) and rainfall index (DSRAIN). Rainfall index has been deseasonalised. The correlation results show that WPIFA is highly correlated with both spot and future prices, while coefficient with futures is marginally higher. Coefficients with rainfall are found to be weak although the sign appear to be consistent. However, as correlation does not say anything about causation, an attempt has been made to understand the causal relationship between these variables within the cointegrating framework. As the basic requirement for any advanced time series analysis is the knowledge of the nature of the univariate processes of the variables, first unit root tests based on Elliott-Rothenberg-Stock DF-GLS test statistic have been estimated and the results are presented in Table 4.

Table 4. Unit root test - Elliott-Rothenberg-Stock (ERS) DF-GLS test statistic (No. of lags-as per AIC): June 2005 to December 2011

Variables	DF-GLS statistic		Inference
	At level	At First difference	
LNSPOT	-2.337	-5.389	I(1)
LNFUT	-2.252	-6.623	I(1)
LNWPIFA	-2.738	-3.200	I(1)
LNWPIFP	-3.365	-2.939	I(1)
DSRAIN	-3.236	-	I(0)

Unit root tests show that all the variables, except DSRAIN, arenon-stationary at levels and stationary at first differences. These results give the option of undertaking cointegration, causality and error correction analysis, which requires all variables to be integrated of the same order while non-stationary at levels. The results of cointegration analysis are presented in Tables 5 to 9.

Table 5. Cointegrating vector (normalised values)
Model: LNSPOT = f (LNFUT, LNWPIFA, LNWPIFP, DSRAIN)

Normalized variable **LNSPOT**	**LNFUT**	**LNWPIFA**	**LNWPIFP**
	0.9956	0.002798	0.12627

(DSRAIN(-2) is stationary exogenous variable)

One cointegrating vector has been identified when LNSPOT, LFUT, LNWPIFA, and LNWPIFP are included.DSRAIN(-2) was included in the system as an exogenous variable. The identified vector is presented in Table-5, which is indicating that there is almost one-on-one long term relationship between spot and future prices. Further ECM model has been estimated and all the variables in the system show expected theoretical signs with ECM term found to be negative and significant. Rainfall appears to affect the spot prices with a lag of two months.

These results suggest that there is strong cointegration between futures price (based MCX AGRI-future index) and the spot prices (MCX AGRI-spot index) of the commodities that is allowed to trade in the futures market. Our causality and impulse response results show that future prices Granger cause spot prices while the shock in futures prices appear to have impact on the spot prices atleast for five month period with a maximum impact with a lag of one month. Changes in rainfall (deseasonalised) index affects both futures and spot prices with different lags.

Table 6. Error correction model (ECM)

ECM for variable LNSPOT estimated by OLS based on cointegrating VAR(6)

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
Ecm1(-1)	-0.11889	0.030867	-3.8518[.000]
DSRAIN(-2)	-0.00003413	0.00001942	-1.7576[.085]

To assess the bivariate causality between the variables of interest, particularly with the rainfall, simple pair-wise Granger causality tests are conducted and are presented in Table 8. Clearly, rainfall does cause the future prices until six lags while its impact on spot prices is only upto four lags. This indicates that the impact of changes in rainfall could last longer on futures prices.

Table 7. Granger Causality Tests:

Null hypothesis	Number of lags	Calculated χ^2 value[Prob]	Conclusion
LnSpot is not Granger caused by Lnfut	5	22.4068[.001]	Reject null hypothesis
LnSpot is not Granger caused by Lnwpifa	5	21.9564[.001]	Reject null hypothesis
LnSpot is not Granger caused by Lnwpifp	5	20.9257[.002]	Reject null hypothesis

Spot and futures prices are strongly cointegrated and at the same time there is bi-directional causation between the variables. However, futures prices cause spot prices for a longer time than vice versa. This result supports the theoretical understanding of the relationship between these two markets. However, it clearly contradicts the conclusions of AbhijitSen Committee. Although there could be other factors that can affect the futures prices, after controlling for fuel prices, our results clearly show transmission mechanism of weather shocks to prices. These are the short term impacts and the medium term impacts could be larger on output and other sectoral prices depending on price pass-through on wholesale prices, which is largely a policy option.

Table 8. Pair-wise Granger causality results

	2 Lags	4 Lags	6 Lags	8 Lags	12 Lags
Null Hypothesis:	**F-Statistic**	**F-Statistic**	**F-Statistic**	**F-Statistic**	**F-Statistic**
FUT does not Granger Cause DSRAIN	0.19	1.72	1.35	0.88	0.69
DSRAIN does not Granger Cause FUT	3.16*	2.22*	1.87*	1.24	0.90
SPOT does not Granger Cause DSRAIN	0.53	1.06	1.04	1.24	0.90
DSRAIN does not Granger Cause SPOT	2.19*	1.91*	1.36	1.04	0.88
SPOT does not Granger Cause FUT	5.45*	2.68*	1.95*	1.66*	1.66*
FUT does not Granger Cause SPOT	0.11	0.45	2.42*	2.04*	1.83*

* indicate statistics is significant

Variance decompositions give the proportion of the h-periods-ahead forecast error variance of a variable that can be attributed to another variable. These therefore measure the proportion of the forecast error variance in spot prices that can be explained by shocks given to its determinants. Results in Table 9 provide normalized (sum equals 100) generalized variance decompositions for up to a 24-month time horizon.

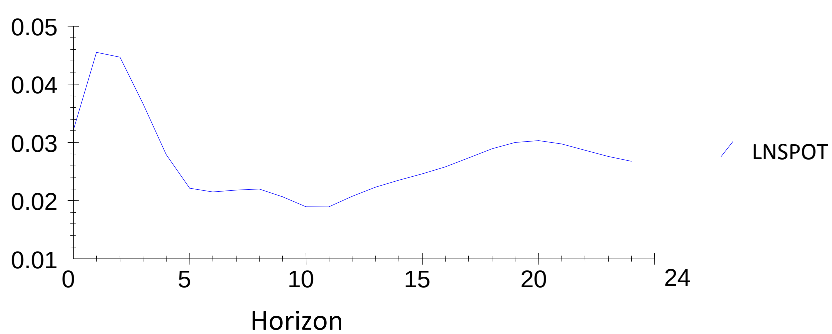
Table 9. Generalized variance decomposition (in percentage terms)

Horizon	LNSPOT	LNFUT	LNWPIFA	LNWPIFP
1	61.29	37.36	0.11	1.25
6	53.58	40.71	0.67	5.04
12	32.97	53.53	5.60	7.96
18	24.79	61.83	8.89	4.57
24	21.26	65.95	9.91	2.98

The table shows that at a forecast horizon of 24 months, over 50% of the forecast error variance in spot prices is explained by future prices. Important determinants of spot prices in descending order of importance include future prices, wholesale prices - food articles, wholesale prices – fuel and power. Note that the forecast error variance decompositions only give us the proportion of the forecast error variance in spot prices that is explained by its determinants. They do not indicate the direction (positive or negative) or the nature (temporary or permanent) of the variation. Thus, the impulse response analysis is used to analyze the dynamic relationship among variables. The direction of changes observed in the impulse responses (Graph-3 to Graph-7) conform to the signs obtained earlier in the cointegrating vector. It is noteworthy that all shocks have a permanent effect on spot prices, which is what we expect given that it is nonstationary.

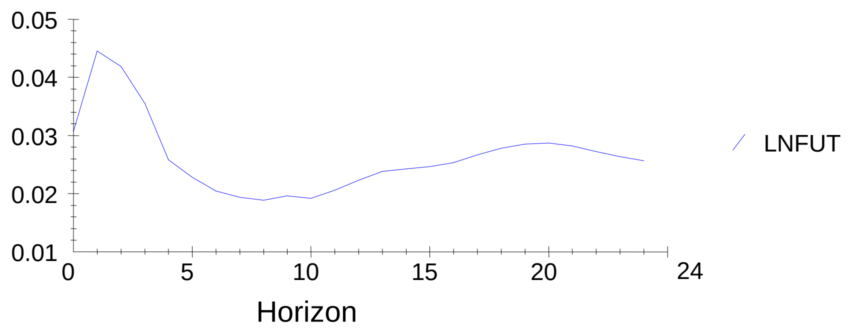
Graph 3

Generalized Impulse Response(s) to one S.E. shock in the equation for LNSPOT



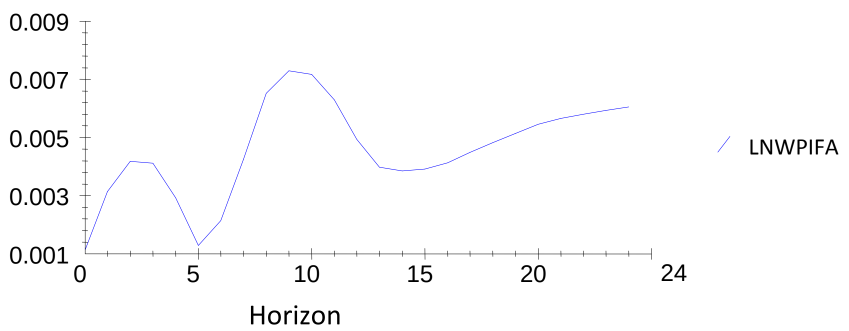
Graph 4

Generalized Impulse Response(s) to one S.E. shock in the equation for LNSPOT



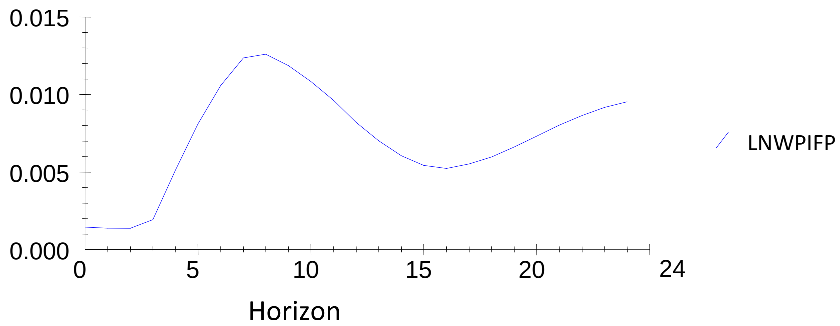
Graph 5

Generalized Impulse Response(s) to one S.E. shock in the equation for LNSPOT



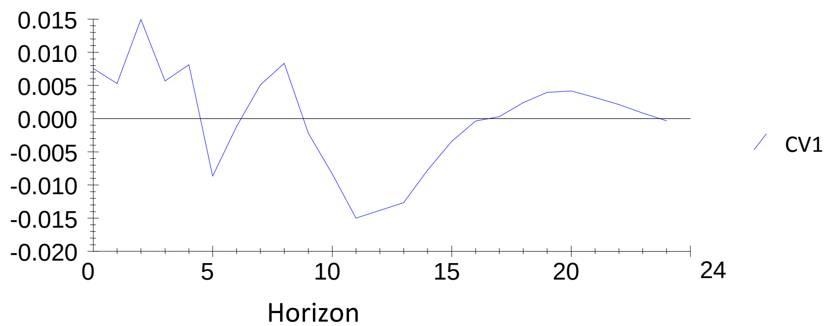
Graph 6

Generalized Impulse Response(s) to one S.E. shock in the equation for LNSPOT



Graph 7

Generalized Impulse Response(s) to one S.E. shock in the equation for LNSPOT



Results from non-linear model

We first estimate the linear model. For rice and pulses, 3rd to 6th lags were found significant, while for wheat, 7th to 10th lags are significant. For all the three variables, the null hypothesis of no nonlinearity was rejected at 5 %. Therefore we estimate the nonlinear models. The results are given in tables A-1, A-2 and A-3. The results clearly show that in the post-transition regime, the lags of rainfall have a significant negative effect, in all the variables, while this is not the case in the pre-transition regime. The points around which the regime-switch is centered are

0.58, 0.50 and 0.47, respectively, which imply, given the total sample size of 144, 83.9, 71.5 and 67.6 months, respectively. These points all lie between June 2005 and December 2006, i.e., after the introduction of the futures markets. This is clearly shown in the transition functions presented in Appendix. While the relationship rainfall with wheat prices show a sharp change, with rice and pulses prices it shows smooth regime change. One explanation could be that the production of wheat is concentrated in one season only, unlike the other two products, leading to much larger response of prices to any news about weather shocks, transmission of which was facilitated by the introduction of futures trading.

Conclusions

The issue of weather shocks and its adverse impact on the prices has come into center stage largely due to its frequent occurrence in the recent period, which is generally attributed to the issue of climate change. One of the institutions that mitigate the adverse impact is the presence of commodity futures market, which is pursued to help both producers and consumers in reducing the risk as well as helping in reducing the price volatility. In India, prior to the introduction of commodity futures market, the commodity prices found to have experienced high volatility. With the introduction of the commodity futures market in India in 2005, it was expected that weather shocks should have had smooth transmission on the general price levels. In this paper, an attempt has been made to understand the transmission mechanism of weather shocks between spot and futures market as well as on the wholesale market prices for food articles. Although futures market is still in a nascent stage with only small set of informed participants, who are hedgers and speculators, the reach of the market to the actual producers and consumers could be limited. In addition, frequent intervention by the government in banning trade must have also affected the growth of the market. However, off-late there is a substantial rise in the volumes, which might be resulting in efficient market outcomes.

With the help of cointegration analysis based on monthly data from June 2005 to December 2011, this study finds that, as expected, there is increasing integration of spot and futures market prices. The impact of rainfall on both the prices is found to be highly significant, indicating that any change in the expected weather conditions could have negative impact on the commodity prices. With the help of error correction model, we find that rainfall affects the spot prices with a lag of two months. Our causality and impulse response functions show that future prices Granger cause spot prices while the shock in futures prices appears to have impact on the spot prices at least for five month period with a maximum impact at a lag of one month. Changes in rainfall affect both futures and spot prices with different lags. The results from the bivariate causality between the variables of interest, particularly with rainfall, support the theoretical relationship between these two markets, which is clearly different from the conclusions of the AbhijitSen Committee. Although there could be other factors that can affect the futures prices, after controlling for fuel prices, our results clearly show transmission mechanism of weather shocks to prices. The results from the variance decompositions and impulse responses only support the direction as well as the extent of impact future prices have on the spot prices. This is further strengthened by the results from our non-linear model, which show that with the introduction of futures market, the relationship between rainfall and prices have strengthened significantly. In other words, futures markets appear to absorb the weather shocks efficiently compared to the regime without futures market.

The conclusions of this study indicate that introduction of futures market in India appear to increasingly helping the overall price discovery process in India by absorbing (smoothening) the exogenous shocks such as weather shocks as well as in reducing the risks. As this result is different from the previous official study, one important lesson could be that there is a need to examine the role of futures market on the domestic prices on a continuous basis until the markets are fully developed. This is also because the results would be robust with an increase in the information set.

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Appendix

Table A-1: LSTR model estimation results for Rice

	Pre-transition		Post-transition	
	Coef	p-value	Coef	p-value
Intercept	0.0163	0.000	0.0975	0.000
Lag 3	-0.0168	0.011	-0.0135	0.060
Lag 4	-0.0119	0.086	-0.0180	0.011
Lag 5	-0.0105	0.108	-0.0177	0.012
Lag 6	-0.0130	0.037	-0.0163	0.023
$\hat{\gamma}$[4]	29.79			
$\hat{\mu}$	0.5824			

Table A-2: LSTR model estimation results for Wheat

	Pre-transition		Post-transition	
	Coef	p-value	Coef	p-value
Intercept	0.0147	0.058	0.0912	0.000
Lag 7	0.0013	0.916	-0.0300	0.002
Lag 8	-0.0062	0.626	-0.0378	0.000
Lag 9	-0.0190	0.126	-0.0441	0.000
Lag 10	0.0128	0.283	-0.0421	0.000
$\hat{\gamma}$	2695.70			
$\hat{\mu}$	0.4967			

Table A-3: LSTR model estimation results for Pulses

	Pre-transition		Post-transition	
	Coef	p-value	Coef	p-value
Intercept	-0.0105	0.418	0.1116	0.000
Lag 3	0.0007	0.968	-0.0413	0.002
Lag 4	0.0027	0.891	-0.0551	0.000
Lag 5	-0.0035	0.846	-0.0429	0.001
Lag 6	-0.0117	0.497	-0.0442	0.001
$\hat{\gamma}$	14.34			
$\hat{\mu}$	0.4696			

[4] In order to get a better grid of values for this parameter, for estimation the argument of the logistic function was divided by the sample standard deviation of the transition variable.

Appendix-Graph: Transition function for food prices