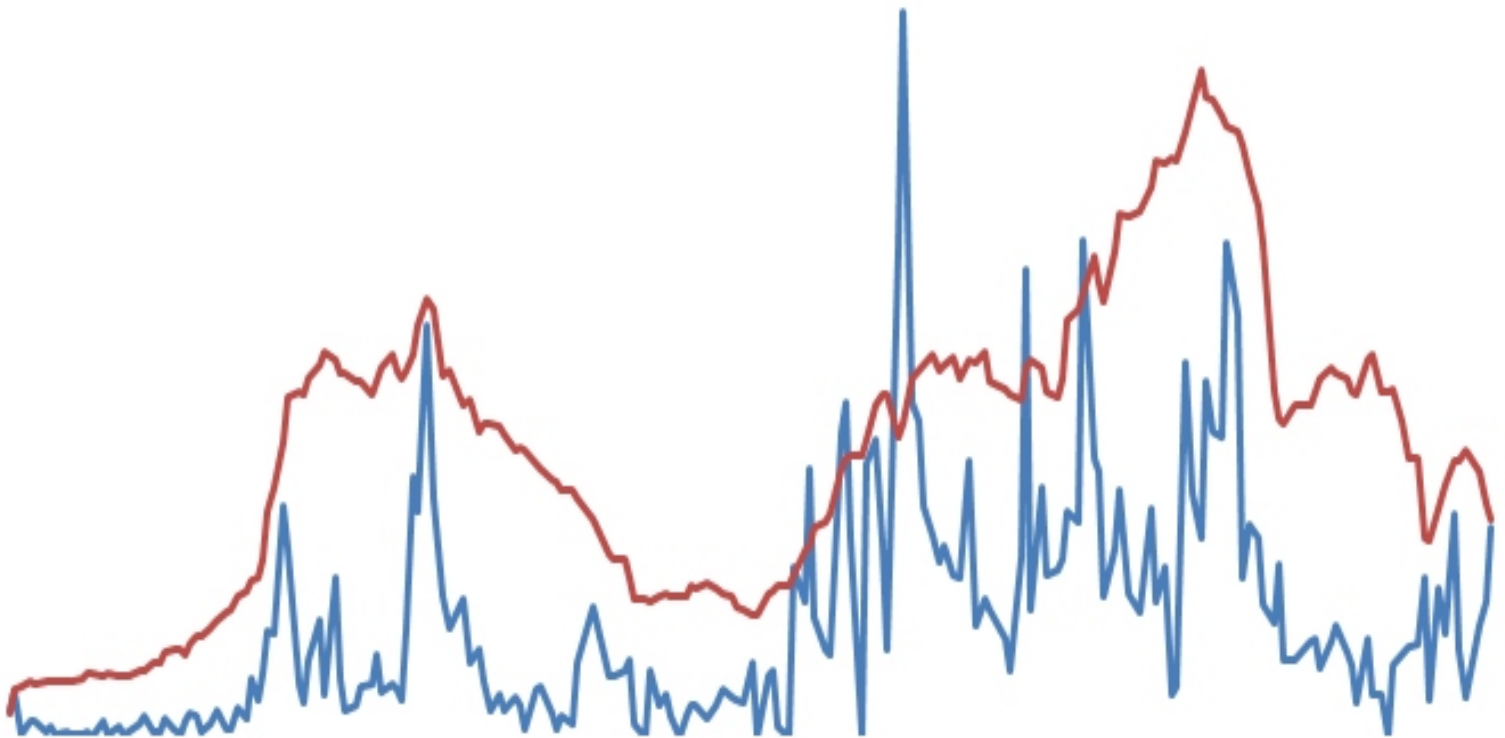


# **Role of Thin Commodity Futures Markets in Physical Market Price Making: An Analysis of Wheat Futures in India in the Post-Ban Era**

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# **Role of Thin Commodity Futures Markets in Physical Market Price Making:**

## **An Analysis of Wheat Futures in India in the Post-Ban Era**

**Nilanjan Ghosh**\*

### **Abstract**

*There is a belief that even thin futures markets can act as a forum for reference pricing and create more volatility in the physical market prices. This article tests that hypothesis, given a few problems affecting the efficiency of the wheat futures markets in India, after the resumption of wheat futures in May 2009 following a ban of more than two years. The article tries to answer three questions: Do physical market players use the futures price of wheat as a reference price? Does the volatility in futures prices cause price volatility in the physical markets? What are the determinants of volume and volatility in the wheat futures markets, as also their interrelation? The article found that there is little evidence to suggest that futures price serves as reference price for transacting contracts in the physical market, and, as a natural corollary, futures market volatility cannot lead to volatility in the physical market. The level of liquidity was low in the futures markets, as the markets were not only bereft of speculative volumes, it did not even seem to have served the purpose of hedgers. Hence, while rejecting the hypothesis set for testing, this article concludes that it is not possible for a thin market, bereft of adequate participation and liquidity, to provide a forum for discovering the reference price for the physical market, and thus it cannot destabilize the latter. These conclusions have been arrived with time series econometric analysis, consisting of Vector Autoregression (VAR) methods, Granger causality tests, Autoregression methods (AR), and seemingly unrelated regression equation methods.*

Keywords: Futures market, Price, Physical Market (Mandi), Volume, Volatility, Open Interest, Arrival.

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\* This is not the final version, but an unpublished draft of an ongoing research, on which comments are welcome. The author gratefully acknowledges extremely helpful comments received so far from Mr. Lamon Rutten, MD and CEO, MCX on an initial draft of this paper. Dr. Madhoo Pavaskar has offered critical comments on a previous draft. The usual disclaimer, however, follows.

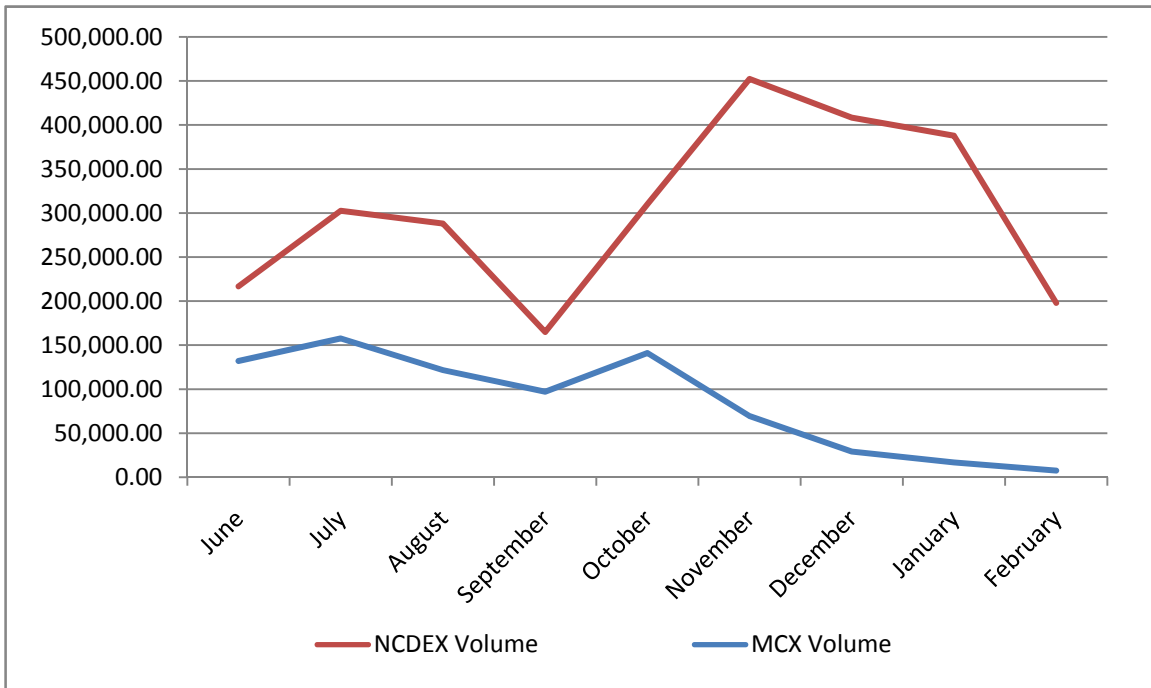
## 1. Introduction

Derivative trading in wheat resumed in commodity futures exchanges in May 2009 after a ban over such trading in the preceding two years. Incidentally, whether the wheat futures ban helped to cool down inflation in the economy is really a debatable issue, especially since the wheat prices in India and abroad ruled high throughout the ban period, thereby proving the tyranny of the market fundamentals rather than the suspected price aggravating role of the futures markets. The ban was lifted after the wheat prices in the country became stable by 2009, as also because various studies revealed that futures markets could not be held responsible for creating inflationary pressures in the economy (Sharma 2009). Interestingly, the ban on futures trading in rice has not yet been lifted, despite the fact that futures trading in wheat and rice were banned on the same day when the Union Budget for 2007-08 was presented. The reason given is that rice, as a commodity, might not succeed in the futures market in attracting either trading volume or open interests, so as to enable the futures platform to perform the functions of price discovery and price risk management.

True, when rice contracts were traded in the futures markets, they did not evince good market interest or turnover. The performance of wheat futures then was not inspiring either. . On the day when wheat and rice futures were banned (February 28, 2007), the volume of trading in wheat on Multi Commodity Exchange of India Limited (MCX), the largest commodity exchange in the country, was zero (Chary 2007). Moreover, the post-ban volume for wheat on National Commodities Derivatives Exchange (NCDEX), which has otherwise better volumes in agro-commodities, has not been significant, too.

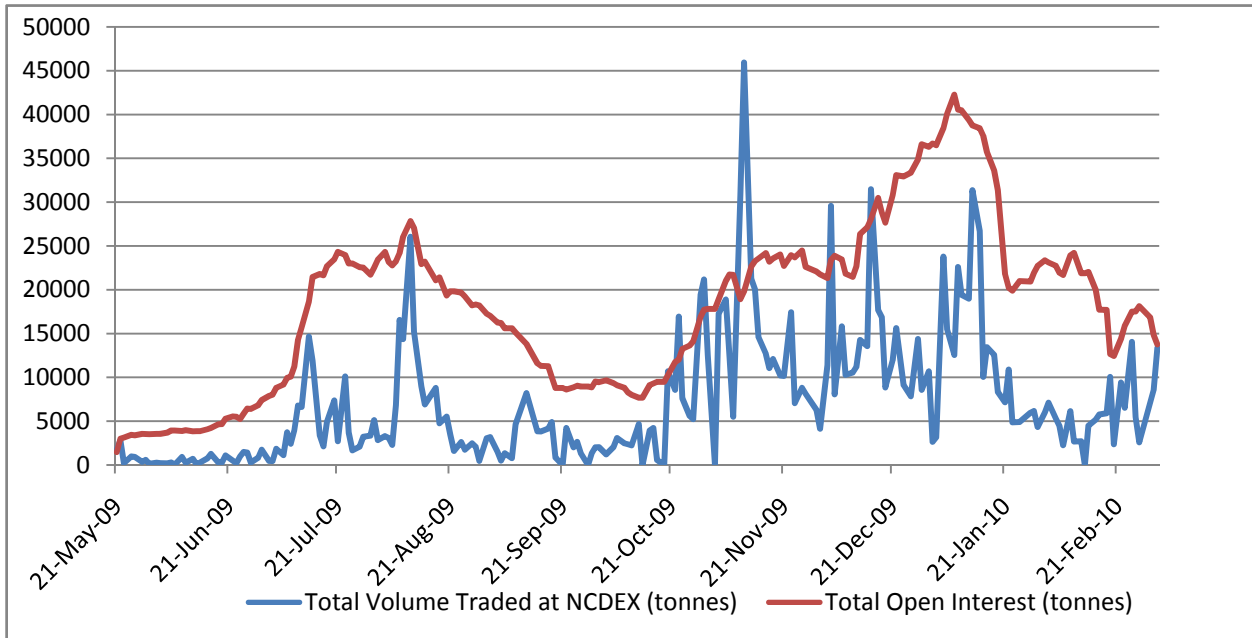
Since the resumption of futures trading in wheat in June 2009, NCDEX has shown much higher trading volumes (*Figure 1*) than MCX, which is essentially a metals and energy exchange.

**Figure 1: Wheat trading volumes at MCX and NCDEX (Tonnes per month)**



Source: MCX intranet

**Figure 2: Volume and Open Interest of Wheat Futures Contracts at NCDEX (tonnes/ day)**



Source: NCDEX website

Though NCDEX has relatively high trading volumes in wheat, the daily volume of trades and open interest at NCDEX (Figure 2) are far from satisfactory. Most of the times, the volume has been below 5000 tonnes in a day, in-between spikes of more than 30,000 tonnes of trades on sporadic occasions notwithstanding. This is just a minuscule fraction of the trades actually taking place in the physical wheat markets (*mandis*) of India. With such low volumes of trade in the wheat futures markets, is it, at all, possible for wheat futures markets to affect either the *mandi* prices or prices of forward contracts traded in terminal wholesale markets? Any commonsensical market participant will answer in the negative. However, a few agricultural econometricians, by a quizzical turn of logic, argue that even thin derivative markets are capable of influencing the physical market prices (e.g. Elumalai et al. 2009; Carter 1989; Karbuz and Jumah 1995; Mattos and Garcia 2004) ). This argument is based on the assumption that even though thin and inefficient for effective hedging, physical market traders tend to follow the price signals from the futures. The low trading volume of thinly traded futures markets may generate a small amount of information of considerably low quality, but can still be useful for the physical market trades by way of reference or benchmark prices. (Elumalai et al. 2009, Carter 1989).

There is no doubt that wheat futures markets in India are thinly traded markets, despite the efforts put by the exchanges to increase the volumes therein. Ghosh et al. (2007) attempted to test the efficacy of the wheat futures markets in the pre-ban era, and could not find any conclusive evidence on the price discovery function of the futures markets. Neither did they find any conclusive evidence of the futures markets causing physical market volatility. None of the analyses on the efficiency of Indian futures markets, however, have considered variables like traded volumes and open interests. Rather, efficiency of futures markets has been defined merely with the price dynamics between the two markets (e.g., Thomas and Karande 2001; Roy 2009; Singh et al 2009).

This article is all about looking at how efficient are wheat futures markets working after the resumption of futures trading. Some of the critical questions it seeks to answer are:

- 1 Does futures price of wheat serve as a reference price for physical-market players?
- 2 What is the extent of volatility in the futures market? Does this volatility increase the price volatility in physical markets?

3 What are the determinants of volume and volatility in wheat futures markets, and what is the nature of their interrelation?

To answer these questions, I have relied on data from NCDEX, as wheat futures trading seems to be relatively more active there than at other futures exchanges, though not encouraging enough according to some of the market functionaries.<sup>1</sup> In Section 2 is presented a brief description of the data and methodology. Section 3 discusses the answers to the various questions posed. Section 4 offers the concluding remarks.

## 2. Data and Methodology

As stated earlier, the daily futures market data have been obtained from the NCDEX website ([www.ncdex.com](http://www.ncdex.com)) for the period from May 21, 2009, to March 4, 2010. For all wheat contracts at NCDEX, the delivery centre is Delhi. On the other hand, the physical market data for the corresponding period have been obtained from the website of Directorate of Marketing and Information, Ministry of Agriculture, Government of India ([www.agmarknet.in](http://www.agmarknet.in)). The physical market considered in this case is the Narela Mandi in Delhi. The reasons for the selection of Narela Mandi in Delhi, for this analysis, are more than one. First, the only delivery centre for the NCDEX wheat futures contract is Delhi. The reason for this might be that Delhi is a major centre for wheat trading, with the adjoining states of Uttar Pradesh, Punjab and Haryana being the largest wheat producing states of the country. Second, Narela Mandi has the highest trading volume in Delhi, and its price is often considered as an “indicator price” in India. The variety of wheat considered is the Mexican variety, which is the basis variety in NCDEX contract, considering the quality characteristics. The Mexican variety is produced more ubiquitously in India than the latter. Data have been obtained on the following variables, with the associated symbols used in the econometric equation given in each parenthesis with the respective variable:

- I. Futures Volume (*F\_Volume*)
- II. Open interest (*OI*)

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<sup>1</sup> Personal communication with Naveen Mathur, Associate Director, Angel Commodities.

- III. Near Month closing futures price (*FP*)
- IV. High price at the futures market (*High\_price*)
- V. Low price at the futures market (*low\_price*)
- VI. Arrivals at the physical market or Mandi (*Arrival*)
- VII. Minimum price quoted at the Mandi (*Min\_price*)
- VIII. Maximum price quoted at the Mandi (*Max\_price*)
- IX. Modal price quoted at the Mandi (*Modal\_price*)
- X. Closing Mandi price (*SP*)

For variables on futures markets, we have considered data for eight contracts with varying maturity periods. The maturity months for the contracts were August 2009, September 2009, October 2009, November 2009, December 2009, January 2010, February 2010, and March 2010. The futures price has been defined by the price of the near month futures contract (the contract whose maturity is most imminent). For the volume of trading and open interest, I have added up the volume traded for the various contracts on a particular day. The same has been done for open interest on a particular day. This has given the total volume and the open interest figures for a particular day in the futures exchange.

I have computed price volatility with the following formula:

$$f\_price\_vol = (High\_price - low\_price) / FP \dots (1)$$

In (1), *f\_price\_vol* indicates futures price volatility quoted on a day. Rather than the average or the closing price, it is usually better to take the modal price in the denominator as that reflects the most frequently quoted price, and normalizes the range (defined by the difference between the maximum and the minimum) around the price at which maximum transaction has taken place. However, the modal price was not available for the futures market.

But, for the physical markets, the modal price was available, and I have normalized the range with the modal price. The formula used is:

$$s\_price\_vol = (SP_{High} - SP_{low}) / SP_{mode} \dots (2)$$

In (2), *s\_price\_vol* is the spot price volatility, *SP<sub>High</sub>* is the maximum physical market price, *SP<sub>low</sub>* is the minimum physical market price, while *SP<sub>mode</sub>* is the modal physical market price.

I acknowledge the fact that this is a very crude measure of price volatility. Readers might even argue that this is not really volatility, as this is merely based on the high and low end prices, and does not consider the entire vector of prices quoted at which transaction has taken place throughout the day. I further acknowledge that my measure of volatility has merely been confined to a “relative range” in the statistical sense, and does not entail the real measure of volatility that actually should have been delineated and estimated by the “coefficient of variation” (or the quotient of standard deviation of the prices and the mean of the prices, multiplied by 100). Yet, there were problems in computation of coefficient of variation. The problem arises with the availability of data on a real time basis on the prices on which transactions have taken place. At the same time, for computation of standard deviation as also the mean, and a true reflection of the coefficient of variation, I also needed the data on the volumes transacted at each quoted price. In the absence of both these types of information, I had to take a crude measure of dispersion, given by “range”, and standardized it by the closing price or the modal price, as available. Hence, given the data constraints, it seems that (1) and (2) are the best possible way out to define intra-day volatility.

Due to the time series nature of the data, before the data gets subjected to any kind of econometric analysis, it is essential to test for *stationarity* in the data. Also known as the unit root test, I have used the standard Augmented Dickey-Fuller (ADF) test to test for the existence of unit roots in the various variables. The econometric package used for the analysis is STATA 10. The results, based on Appendix 1, are given in Table 1.

**Table 1: Results from the ADF Test**

<b>Variable</b>	<b>Does Unit Root Exist?</b>
Futures Volume (F_volume)	No
Open Interest (OI)	No
Futures Price (FP)	Yes
Mandi Price (SP)	No
Mandi Price Volatility (s_price_vol)	No
Futures Price Volatility (f_price_vol)	No
Arrival at the Mandi (Arrival)	No

Table 1 shows that all the variables, except FP, are stationary. Hence, in case any regression analysis on FP by relating it with the other associated variables need to be conducted, one needs to take the first difference and check whether the series is “difference stationary.” The new series with the first difference is created and is found to be stationary. As a result, to avoid spurious regressions, this new series has been taken for the main analysis.

In the main analysis, first of all, I have conducted a Vector Autoregression (VAR) followed by Granger causality test to test whether a direction of causality exists between futures price series (considering the difference stationary given by *Fp\_first\_diff*) and physical market prices. This will provide an indicative answer to my first question on the role of futures prices as the “reference price” for the physical market under consideration. Though, apparently, I am talking of only one physical market here, let me reiterate that Narela Mandi is a very important Mandi, being the biggest regulated market for food grain in Delhi. Hence, this might roughly indicate whether futures market is, at all, integrated to this physical market, and also physical markets of similar characteristics. To answer the second question, I have estimated the volatility in the futures and physical markets with the formulae (1) and (2), and have used the following ARIMA (2,0,0) or AR (2) regression equation:

$$s\_price\_vol = \alpha + \beta.f\_price\_vol + \eta.f\_vol\_lag + \gamma.s\_vol\_lag + \lambda_1.s\_price\_vol(-1) + \lambda_2.s\_price\_vol(-2) + \omega \quad \dots(3)$$

Because all the variables involved in (3) have been found to be stationary, hence, ARIMA (2, 0,0) or AR (2) series is supposed to give efficient results. In (3), *f\_vol\_lag* indicates the first lag in futures volume, *s\_price\_vol (-1)* indicates the lag of first order in physical price volatility for the AR process, while *s\_price\_vol (-2)* indicates the lag of second order in physical price volatility for the AR process.

Finally, to answer the third question, I have first conducted a VAR with two lags between futures price and volume, followed by the Granger causality test. By establishing the degree of dependence as also the direction of causality between the two variables, I have then attempted to run the following system regressions.

$$f\_price\_vol = \phi(F\_volume, arrival, OI) \dots (4)$$

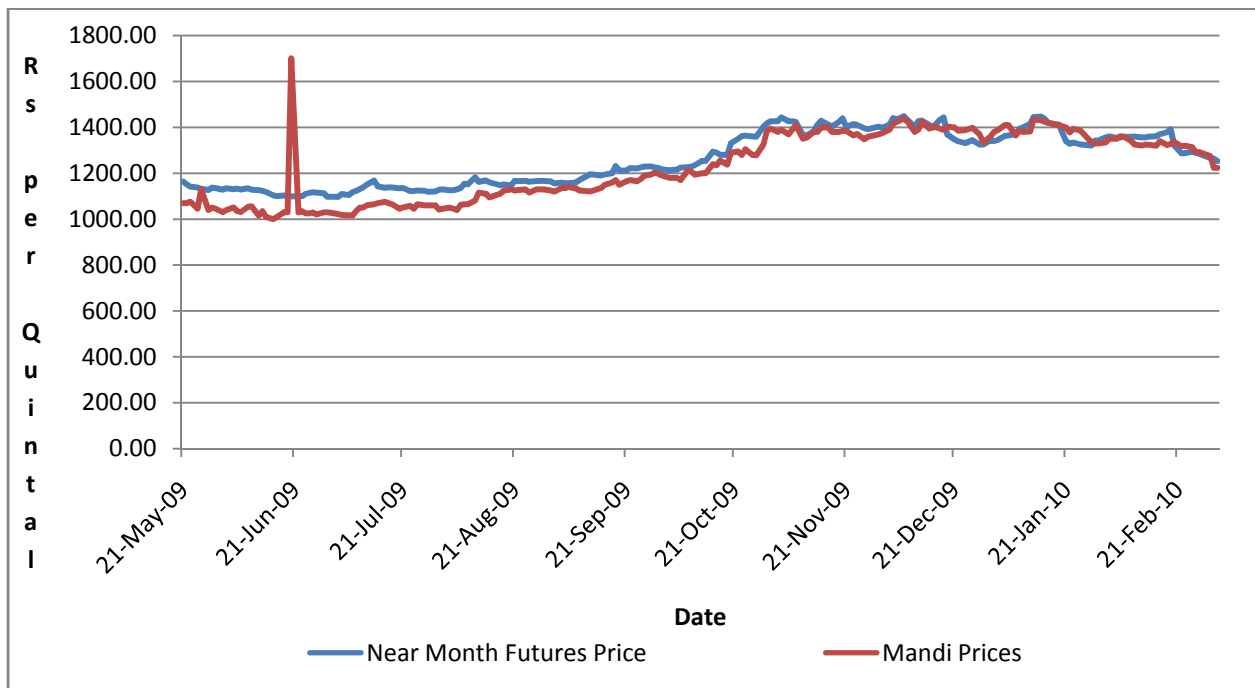
$$F\_volume = \varphi(s\_price\_vol, f\_price\_vol, arrival, OI) \dots (5)$$

Equations (4) and (5) will offer the degree and nature of the interrelations between the two variables, as also the effects of open interest and arrival at *mandi* on futures volume and futures price volatility.

### 3. Propositions, Results, and Discussions

I will now take up each of the questions, formulate the propositions, show the results, and discuss them. For the first question, despite a number of researches on wheat futures markets that stress their roles in market integration, my contention still goes in favour of the market participants who feel that low volumes in futures markets can never result in price making. There is, however, something more interesting that I would like to present here before I get into the econometric exercise. As one examines *Figure 3*, one finds that there apparently seems to be a high correlation between the futures and mandi prices.

**Fig. 3: Futures Price and Mandi Price of Wheat (Rs. per Quintal)**



Source: Author's compilation from [www.ncdex.com](http://www.ncdex.com) and [www.agmarknet.in](http://www.agmarknet.in)

In fact, the correlation coefficient between the physical market price and the futures price has been found to be as high as 0.924. Yet, it needs to be realized that such relation might be spurious as both prices might be affected by some common yet factors related to market fundamentals that can create a “non-sense” relation. As it is, the futures price has been found to be non-stationary, and we have already taken the first difference to avoid the unit root. This clearly exhibits the existence of a spurious relation between the futures and the physical market prices. Hence, my position is just the opposite of what has been presented in *Figure 4*.

*Proposition 1: Under low volume conditions in futures markets for wheat, it is unlikely that physical market players will take up futures prices as the reference price.*

Appendix 2 shows the results of the VAR, as also the Granger causality test. In the VAR model it becomes clear that the futures price does not take up any autoregressive lag, and neither the two lags in the physical market prices affect it. On the other hand, the physical market, in no way, shows any dependence on the futures prices’ first and the second lags. Physical market price, however, gives strong evidence of being in autoregression. At the same time, the Granger causality test clearly shows that there is no existence of causality between the futures and the physical market price of wheat. Hence, there is no indicative evidence of the physical-market players considering the futures prices as reference price for wheat.

This apparently establishes the inefficiency of the wheat futures market, and its inability to act as a forum for reference prices for the physical market. From this, it seems that there cannot be much evidence of futures price volatility affecting physical market price volatility. Hence goes my proposition 2.

*Proposition 2: With futures and physical market prices being independent, there is no scope of futures market affecting the intra-day volatility of the physical market.*

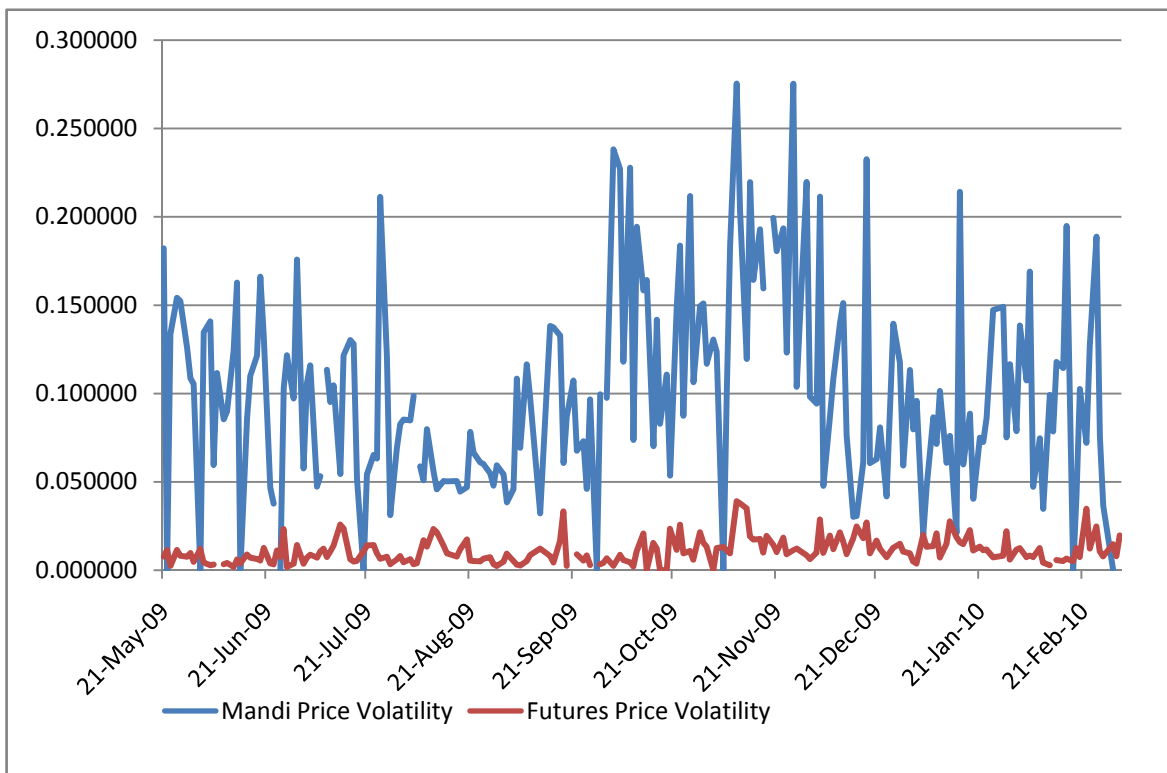
To reinforce this contention, I have run the ARIMA (2, 0, 0), or AR (2). The equation emerging from the results, as given in Appendix 3, can be rewritten as:

$$\begin{aligned}
 s\_price\_vol = & 2.566 + 0.068 \cdot arrival + 0.072 \cdot f\_price\_vol - 0.061 \cdot f\_vol\_lag \\
 & \quad (0.00) \quad (0.066) \quad (0.132) \quad (0.43) \\
 & + 0.112 \cdot s\_price\_vol(-1) + 0.127 \cdot s\_price\_vol(-2) \quad \dots(6) \\
 & \quad (0.16) \quad (0.216)
 \end{aligned}$$

The figures in the parentheses reflect on p-values. As can be seen from (6), arrival at the *mandi* might influence physical market price volatility, though there is no indication of futures price volatility, neither its first lag affecting the same. None of the autoregressed coefficients (first and second lags of physical market price volatility) have been found to be significant. This result further reinforces the independence of the physical market from the futures market.

As it is, the volatility in the physical market is much higher than that of the futures market. This can be seen from *Figure 4*. One of the reasons of low levels of participation of speculators and day-traders is low volatility. This is because day-traders survive on intra-day margins. A low volatility on the futures platform might not be too lucrative for these players to play in the futures markets. In futures markets for more liquid commodities, around 75-80% of the market is dominated by day-traders, scalpers, and jobbers. They are the ones who offer liquidity to the market, and their roles in market making and price discovery have been well documented (Pavaskar and Ghosh 2008).

**Fig. 4: Intra-day Price Volatility in Futures and Physical Markets**



Source: Author's estimates

As a result, in most of the liquid markets, the open interest as a proportion of trading volume is generally low. However, for wheat, this proportion is very high (*Figure 3*). In fact, during most of the period, open interest has been more than volume. This indicates very low levels of participation of the day traders, scalpers, and jobbers, thereby making the market thin. It is quizzical that such a thin market does not even reveal adequate volatility, which usually characterizes thin markets due to large differences in bid and ask prices. In any case, this analysis, however, has not considered bid and ask data, but only the prices at which transactions have taken place. Consideration of the bid–ask spread at real-time might bring in another dimension to the analysis.

Yet, the crucial question that still remains is: does volume and volatility affect each other? What are the determinants of each? This brings me to my third proposition that is related to the relation between volume and volatility in the futures market.

*Proposition 3: At low volume, as is evident in wheat futures markets, a rise in volume will only be associated with a rise in volatility. On the other hand, a rise in volatility might necessarily result in obtaining more volumes in the markets.*

The VAR model suggests the statistically significant effect of the first lag of futures price volatility on volume (*Appendix 4*). There is also evidence of the two lags of futures volume affecting the trading volume variable. On the other hand, there are some indications that futures price volatility gets affected by the second lag of volume, as revealed by the VAR. The Granger causality test, however, suggests the existence of causality from both directions (i.e. from volume to volatility in the futures market, and vice versa). This brings me to the next quest for deciphering the nature of the relation.

To comment on the nature of the relation, as also to find the possible effects of some other variables, I have run regression equations given in (4) and (5), treating them as “seemingly unrelated regressions,” and using Zellner’s techniques. The results, as given in Appendix 4, can be re-written as:

$$f\_price\_vol = 10.185 + 0.503.F\_volume - 0.018.arrival - 1.001.OI$$

(0.00)
(0.00)
(0.823)
(0.00)

$$R^2 = 0.1043, RMSE = 1.027 \dots (7)$$

$$F\_volume = 14.577 + 0.994.f\_price\_vol - 0.131.s\_price\_vol + 0.0952.arrival + 1.867.OI$$

(0.00)
(0.00)
(0.312)
(0.392)
(0.00)

$$R^2 = 0.3948, RMSE = 1.43 \dots (8)$$

The figures in the parentheses reflect on the p-values. Equation (7) shows that an increase in futures volume increases the volatility in the futures prices. This is precisely because the markets are thin, and increase in participation destabilizes the price positions. On the other hand, increase in open interests leads to lowering of the price volatility. This is because rising open interests reflect on the positions of those who intend to take a relatively more long-term position in the market, and this tends to settle the market, rather than unsettling it. Arrival in the *mandis* does not play any significant role in determining futures price volatility.

From (8), it is clear that a rise in futures price volatility can lead to more volume, while an increase in open interest can also lead to an increase in trading volume. As stated earlier, the volatility in the futures market is low, and this can be stated as one of the reasons for low volumes in the futures market. Neither the price volatility in the physical market, nor the volume of arrivals in that market plays any role in determining volume of trading in the futures markets.

From (7) and (8), it is amply clear that none of the physical market variables have any role to play in the volume and volatility in the futures markets. This reinforces my previous contention of independence of the futures and the physical markets.

#### 4. Concluding Remarks

A few important points have emerged from this analysis. The first is on the ineffectiveness of the futures market in wielding any influence on physical market prices. This might be a foregone conclusion for market participants, but not so much for academicians. This analysis contested the possibility of thin wheat futures markets of discovering prices. Rather it has found that the two markets, willy-nilly, are not taking information from each other. Neither the futures market takes up any information on arrival, prices, and so on in the physical market, nor do physical-market players consider any information from the futures platform.

Add to that the fact that Delhi is the centre for physical delivery as mentioned in the futures contract. Even if small when compared to the physical market, physical deliveries take place. Ideally, the delivery locations should be chosen where the physical and futures market prices are somehow correlated. However, though one may argue the high degree of correlation between the two prices as stated earlier, unfortunately that does not take away the fact of futures markets' futility in the price making process, as shown in this analysis.

The second element arises with the notion of price stabilization or de-stabilization function of the futures market. There is generally a low volume and low volatility in the futures market, and there is no evidence of this volatility affecting the physical-market price volatility. There, thus, seems to be a misconceived perception that futures market will destabilize the physical-market prices. The low liquidity associated with low volatility in the futures platform also confirms the poor participations of speculators, jobbers, and day-traders who are supposed to provide liquidity to the market. The key reason behind the lack of liquidity in the wheat futures market seems to be on the question of lack of speculators who are supposed to take up hedger's risk. Low volatility has, of course, not helped in attracting such investors in the futures markets.

The third remark is more policy-oriented than anything else. With the kind of price relation that exists, it definitely drives away fear from the minds of the policymakers that futures markets can cause price rise in the physical market during shortages. Quite unfortunately, while this contention is misplaced, as an efficient futures market merely signals the forthcoming availability with its price; a thin and inefficient futures market like the wheat futures cannot even do so. Given this condition, there are apprehensions whether the wheat futures market is, at all, playing the important role of price risk management, with hardly much participation of speculators to take up the hedgers' risk.

One critical factor that acts against working of wheat futures markets is the existence of minimum support prices (MSP), and the government's procurement mechanism. Of course, it seems difficult for essential commodities to succeed in achieving volumes in futures exchanges till the MSP exists, which acts as a "put option" for hedgers (Ghosh 2010). Hence, wheat futures market presently is a forum that is of little interest to both speculators and hedgers, and as a result, is bereft of adequate participation to perform its functions.

The objective of this paper is not merely to report on the (in)efficiency problems of the futures markets. It also had the objective to comment on the hypothesis that thin futures market can destabilize physical markets, in case the former acts as a forum for reference price. Though I do not intend to generalize my finding so as to contest or support the above proposition, this paper finds indications of the problems of thin markets, bereft of adequate participation and liquidity, to act as a forum for discovering the reference price, and thus it does not have the ability to destabilize physical markets. However, I will be able to argue more convincingly against the hypothesis under quotation only when I carry out the exercise with more commodities, for which thin futures markets exist. This remains an agenda for future research.

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## Appendix 1: Results of ADF Tests on various variables

dfuller F\_Volume, lags(0)

Dickey-Fuller test for unit root Number of obs = **202**

	Test Statistic	----- 1% Critical Value	Interpolated Dickey-Fuller ----- 5% Critical Value	----- 10% Critical Value
Z(t)	<b>-9.620</b>	<b>-3.476</b>	<b>-2.883</b>	<b>-2.573</b>

Mackinnon approximate p-value for Z(t) = **0.0000**

. dfuller OI, lags(0)

Dickey-Fuller test for unit root Number of obs = **202**

	Test Statistic	----- 1% Critical Value	Interpolated Dickey-Fuller ----- 5% Critical Value	----- 10% Critical Value
Z(t)	<b>-4.235</b>	<b>-3.476</b>	<b>-2.883</b>	<b>-2.573</b>

Mackinnon approximate p-value for Z(t) = **0.0006**

. dfuller FP, lags(0)

Dickey-Fuller test for unit root Number of obs = **202**

	Test Statistic	----- 1% Critical Value	Interpolated Dickey-Fuller ----- 5% Critical Value	----- 10% Critical Value
Z(t)	<b>-1.082</b>	<b>-3.476</b>	<b>-2.883</b>	<b>-2.573</b>

Mackinnon approximate p-value for Z(t) = **0.7223**

. dfuller SP, lags(0)

Dickey-Fuller test for unit root Number of obs = **202**

	Test Statistic	----- 1% Critical Value	Interpolated Dickey-Fuller ----- 5% Critical Value	----- 10% Critical Value
Z(t)	<b>-3.196</b>	<b>-3.476</b>	<b>-2.883</b>	<b>-2.573</b>

Mackinnon approximate p-value for Z(t) = **0.0202**

. dfuller arrival, lags(0)

Dickey-Fuller test for unit root Number of obs = **188**

	Test Statistic	----- 1% Critical Value	Interpolated Dickey-Fuller ----- 5% Critical Value	----- 10% Critical Value
Z(t)	<b>-6.508</b>	<b>-3.481</b>	<b>-2.884</b>	<b>-2.574</b>

Mackinnon approximate p-value for Z(t) = **0.0000**

. dfuller S\_price\_Vol , lags(0)

Dickey-Fuller test for unit root Number of obs = 202

Test Statistic	Interpolated Dickey-Fuller			
	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	-11.965	-3.476	-2.883	-2.573

Mackinnon approximate p-value for Z(t) =0.0000

. dfuller f\_price\_vol , lags(0)

Dickey-Fuller test for unit root Number of obs = 202

Test Statistic	Interpolated Dickey-Fuller			
	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	-12.595	-3.476	-2.883	-2.573

Mackinnon approximate p-value for Z(t) =0.0000

. dfuller OI , lags(0)

Dickey-Fuller test for unit root Number of obs = 202

Test Statistic	Interpolated Dickey-Fuller			
	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	-4.235	-3.476	-2.883	-2.573

Mackinnon approximate p-value for Z(t) =0.0006

. dfuller arrival , lags(0)

Dickey-Fuller test for unit root Number of obs = 188

Test Statistic	Interpolated Dickey-Fuller			
	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	-6.508	-3.481	-2.884	-2.574

Mackinnon approximate p-value for Z(t) =0.0000

dfuller FP\_first\_diff , lags(0)

Dickey-Fuller test for unit root Number of obs = 201

Test Statistic	Interpolated Dickey-Fuller			
	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	-12.812	-3.476	-2.883	-2.573

Mackinnon approximate p-value for Z(t) =0.0000

## Appendix 2:

Sample: 4 - 203 200  
 Log Likelihood = 936.9158 AIC = -9.269158  
 FPE = 3.23e-07 HQIC = -9.20242  
 Det(Sigma\_ml) = 2.92e-07 SBIC = -9.104243

Equation	Parms	RMSE	R-sq	chi 2	P>chi 2
FP_firrst_diff	5	.012066	0.0204	4.167261	0.3838
SP	5	.046106	0.8607	1235.705	0.0000

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
<b>FP_firrst_d-f</b>						
FP_firrst_d-f						
L1.	.0997393	.0706101	1.41	0.158	-.0386539	.2381325
L2.	-.0852213	.0702281	-1.21	0.225	-.2228658	.0524232
SP						
L1.	-.0060168	.0164452	-0.37	0.714	-.0382488	.0262151
L2.	-.0005855	.0164317	-0.04	0.972	-.0327911	.0316202
_cons	.0473473	.0501087	0.94	0.345	-.0508638	.1455585
<b>SP</b>						
FP_firrst_d-f						
L1.	.3609256	.2698052	1.34	0.181	-.167883	.8897341
L2.	.1107337	.2683456	0.41	0.680	-.415214	.6366814
SP						
L1.	.4845291	.062838	7.71	0.000	.361369	.6076893
L2.	.4629629	.0627867	7.37	0.000	.3399033	.5860224
_cons	.3736716	.1914681	1.95	0.051	-.001599	.7489421

. vargranger

Granger causality Wald tests

Equation	Excluded	chi 2	df	Prob > chi 2
FP_firrst_diff	SP	.90396	2	0.636
FP_firrst_diff	ALL	.90396	2	0.636
SP	FP_firrst_diff	2.0791	2	0.354
SP	ALL	2.0791	2	0.354

### Appendix 3

ARIMA regression

Sample: 2 - 203, but with gaps

Number of obs = 195

Wald chi2(5) = 11.65

Log likelihood = -204.8529

Prob > chi2 = 0.0399

S_price_Vol	Coef.	OPG Std. Err.	z	P> z	[95% Conf. Interval]
<b>S_price_Vol</b>					
arrival	-.0681991	.0370743	-1.84	0.066	-.1408635 .0044653
f_vol_lag	-.0611468	.0774154	-0.79	0.430	-.2128782 .0905846
f_price_vol	.0720471	.0478176	1.51	0.132	-.0216738 .1657679
_cons	2.566433	.4980532	5.15	0.000	1.590266 3.542599
<b>ARMA</b>					
ar					
L1.	.1124067	.0800394	1.40	0.160	-.0444677 .2692811
L2.	.1272727	.1028703	1.24	0.216	-.0743493 .3288947
/sigma	.6914266	.0279727	24.72	0.000	.6366012 .746252

## Appendix 4

. varbasic F\_Volume f\_price\_vol, lags(1/2) step(8)

Vector autoregression

Sample: <b>3 - 203</b>	No. of obs	= <b>201</b>
Log likelihood = <b>-655.7031</b>	AIC	= <b>6.623912</b>
FPE = <b>2.581003</b>	HQIC	= <b>6.690412</b>
Det(Sigma_ml) = <b>2.336503</b>	SBIC	= <b>6.788255</b>

Equation	Parms	RMSE	R-sq	chi 2	P>chi 2
F_Volume	5	1.67996	0.2438	64.8174	0.0000
f_price_vol	5	1.0977	0.0688	14.85038	0.0050

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
<b>F_Volume</b>						
F_Volume						
L1.	.3736528	.0806709	4.63	0.000	.2155407	.5317648
L2.	.1597482	.0801353	1.99	0.046	.0026859	.3168106
f_price_vol						
L1.	-.4395643	.1234917	-3.56	0.000	-.6816035	-.1975251
L2.	-.1705184	.1248325	-1.37	0.172	-.4151856	.0741488
_cons	6.508282	.8250089	7.89	0.000	4.891294	8.12527
<b>f_price_vol</b>						
F_Volume						
L1.	-.0605921	.0527107	-1.15	0.250	-.1639032	.042719
L2.	-.1000735	.0523608	-1.91	0.056	-.2026988	.0025517
f_price_vol						
L1.	.1109061	.08069	1.37	0.169	-.0472434	.2690556
L2.	.1063773	.0815661	1.30	0.192	-.0534894	.2662439
_cons	4.81794	.5390645	8.94	0.000	3.761393	5.874487

. vargranger

Granger causality Wald tests

Equation	Excluded	chi 2	df	Prob > chi 2
F_Volume	f_price_vol	20.644	2	0.000
F_Volume	ALL	20.644	2	0.000
f_price_vol	F_Volume	10.943	2	0.004
f_price_vol	ALL	10.943	2	0.004

. sureg (f\_price\_vol = F\_Volume arrival 0l) (F\_Volume = f\_price\_vol S\_price\_Vol arriva  
> 0l)

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi 2	P
<b>f_price_vol</b>	<b>196</b>	<b>3</b>	<b>1.027115</b>	<b>0.1043</b>	<b>141.50</b>	<b>0.0000</b>
<b>F_Volume</b>	<b>196</b>	<b>4</b>	<b>1.430197</b>	<b>0.3948</b>	<b>257.65</b>	<b>0.0000</b>

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
<b>f_price_vol</b>						
F_Volume	.5035728	.0430839	11.69	0.000	.4191299	.5880156
arrival	-.0179849	.0801909	-0.22	0.823	-.1751561	.1391863
0l	-1.00186	.1430791	-7.00	0.000	-1.28229	-.7214299
_cons	10.18586	1.513458	6.73	0.000	7.219539	13.15219
<b>F_Volume</b>						
f_price_vol	.9936646	.0844826	11.76	0.000	.8280816	1.159247
S_price_Vol	-.1313287	.1299801	-1.01	0.312	-.3860851	.1234277
arrival	.0952238	.1113311	0.86	0.392	-.1229811	.3134286
0l	1.867733	.1769891	10.55	0.000	1.520841	2.214625
_cons	-14.57761	2.099873	-6.94	0.000	-18.69329	-10.46194