Law of One Price Arbitrage: A Study on Wholesale Potato Market in Hooghly District of West Bengal, India

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Abstract
The marketing efficiency of wholesale potato market in Hooghly district of West Bengal is investigated through the cointegration and error correction methods framework. The study found that the three wholesale markets of the district viz. Pandua, Sheorafuli and Chapadanga were spatially cointegrated. Though the potato markets of the district are cointegrated, they support only weak form of market integration. Good transportation, network communication and close proximity of the markets are the main factors for this spatial market integration.

Key Words: market cointegration, efficiency, error correction, speed of adjustment

INTRODUCTION
Perfectly competitive markets are distinguished by features such as large number of buyers and sellers, perfect knowledge about market conditions (particularly of prices and quality of product), homogeneity of product, free mobility of buyers, sellers and products. Thus, a single price will prevail in all the markets. Price differential for a particular commodity arising from place, time and from differences would correspond closely to the cost incurred in providing the respective transportation, storage and processing facilities. The market will perform efficiently and there will be no scope for traders to make excessive profits. The pricing system would facilitate exchange and fully reflect the underlying supply and demand conditions (Baharumshah and Habibullah, 1994). However, imperfectly competitive markets are generally taken as important causes for the existence of differential price movements in different markets. It is believed that prices quoted are a reflection of the conditions prevalent in the markets. Therefore, if there are imperfections in the form of either oligopoly power among buyers or unequal information among sellers, then it is expected that buyers will be able to reap abnormal returns and subsequently, wide intra-regional price differential exist in the market.

The competitiveness in a market can be analyzed by different ways. One of the sophisticated techniques to analyze the competitiveness in the market is whether price movements reflect a state of competitiveness in the market. More specifically, this technique uses the time series techniques of cointegration and error correction mechanism to look into the strength of competitiveness in the market. In this paper I have used this method of analyzing the competitiveness in the wholesale potato market in the Hooghly district of West Bengal.

Potato is one of most popular cash crops of the farmers of West Bengal. In the cropping pattern changing scenario of the state, it has been observed that in the south Bengal districts of the state, the farmers are adopting potato as their main cash crops instead of jute, mainly because of its high yield, comparatively less maturity period and high profitability. Even though its cost of cultivation is very high, it has gained wide popularity in the state. Hooghly, the largest potato-producing district in the state accounts for 30.47 per cent of total potato production of the state in 2000-01. In 2007-08, the district produces 2350.04 thousand tonnes of potato which accounts 40 per cent of the total production of the state.

However, one major concern of potato cultivation is the high price volatility and uncertainty of this profitable crop. Sometimes the minimum sale price of potato goes down much below the cost of cultivation and this happens more or less every two or three years. So, from the welfare point of view it is required that perfectly competitive market conditions should prevail in the potato markets of the district so that the free flow of information regarding price, volume of trade, and other technical points can be ensured across all the marketing agents such as potato farmers, traders, retailers and wholesalers.

The issue of market integration in agricultural commodity prices has been studied extensively by numerous researchers both at the national and international levels. Intodia (2005) had shown that the eastern Indian tea auction markets were statistically cointegrated but not the south Indian markets during the period 1999 to 2003. Basu and Dinda (2003), applying the error correction method, have shown the interdependence and high level of efficiency in the potato auction markets in West Bengal. In another study, Behura, Debdutt and D.C. Pradhan (1998) have studied the spatial integration in shrimp markets in Orissa. At the international level, George and Piero (2003), Line L. K. and T. Helene Ystanes F (2010), Crina Viju, James Nolan and William A. Kerr (2006) etc. are some of the recent studies of application of time series econometrics to look into the spatial market integration. However, there is dearth of literature of studying the market efficiency and integration of agricultural commodity markets in India in recent past.

Under this backdrop, this paper analyses the extent of market efficiency in the wholesale potato market in Hooghly district of West Bengal. Three major wholesale markets in the district viz. Chapadanga, Sheorafuli and Pandua have...
been considered for this study. As already mentioned that the fundamental issue when analyzing the market efficiency is the extent to which price movements in one market respond to changes in price movements in other markets. Price transmission from one market to other market is central in understanding the extent of the integration of economic agents into the market process. It essentially means that price movements in various markets are transmitted to other markets effectively. So, if these three wholesale markets are not integrated, the correct price signals will not be transmitted through the marketing channels, and as a result of which the potato growers as well as traders will not be able to specialize according to long-term comparative advantage and the gains from trade will not be realized. In addition to this, the price transmission parameter values consist of key building blocks and play an important role in determining the direction, magnitude and distribution of welfare effects of regional as well national trade policy scenarios. The specific objectives of this paper are:

1. To evaluate empirically the spatial integration of wholesale potato markets in Hooghly district of West Bengal.
2. If they are cointegrated at all, what is the speed of transmission of price signal among the various markets?

The broad structure of the paper is as follows:

After the introduction in section I, section II deals with the hypotheses of the study followed by section III where the data and methodological aspects of the study have been discussed. Then section IV covers the results and discussion of the study. Lastly, the conclusion and policy implication are presented in section V.

HYPOTHESIS

The following hypotheses were tested in this paper:

Hypothesis 1: The wholesale potato markets in Hooghly district are cointegrated.

Hypothesis 2: The strength of the market integration is strong enough so as to transmit the price signals across the markets in the district.

MATERIALS AND METHODS

The data pertaining to the potato prices were collected from the website of AGMARKNET, Directorate of Marketing & Inspection (DMI), Ministry of Agriculture, Government of India. The daily wholesale prices of potato at the three major auction markets of the district viz. Chapadanga, Pandua and Sheorafuli were collected and compiled for the period 1st July, 2010 to 22nd July, 2011.

Almost every empirical study using time series data starts with the testing of the stationarity of the time series data. For these purpose Correlogram analysis and Augmented Dickey Fuller Test for unit root are used. A series is said to be stationary if the mean and covariance are constant over time and the auto-covariance of the series depends only on the lag between two time periods not the actual time at which the covariance is computed. First, the stationarity of the series is tested on the basis of autocorrelation function (ACF) and correlogram. The ACF at lag k is defined as

\[ \rho_k = \frac{\text{covariance at lag } k}{\text{variance}} = \frac{\sum (y_t - \bar{y})(y_{t+k} - \bar{y})}{\sum (y_t - \bar{y})^2} = \frac{\gamma_k}{\gamma_0} \]

\[ \rho_k \text{ is pure number and it lies between -1} \text{ and } +1. \text{ If we plot } \rho_k \text{ against } k, \text{ the graph we get is known as correlogram.} \]

The autocorrelations at various lags for a purely white noise process hover around zero. Now if the correlogram of a time series resembles the correlogram of a white noise time series, then the time series is stationary. However, generally for a non-stationary time series the autocorrelation coefficient starts at a very high value and declines very slowly towards zero as the lag lengthens. One practical question that arises is the choice of the lag length. The rule of thumb is to compute ACF up to one-third to one-quarter the length of the time series. Generally, we start with sufficient large lags and then reduce the lag length by using the statistical criterion Akaike or Schwarz information criterion.

The statistical significance of the all the \( \rho_k \) can be tested by using the Q statistic developed by Box and Pierce.

\[ Q = n \sum_{k=1}^{m} \rho_k^2 \quad \text{where } n = \text{sample size and} \]

\[ m = \text{lag length} \ldots \ldots \ldots 2) \]

While performing ADF test we proceed by considering the following equation:

\[ \Delta Y_t = b_0 + a_0 t + a_1 Y_{t-1} + \sum_{i=1}^{p} (b_i \Delta Y_{t-i}) + \varepsilon_t \ldots \ldots 6) \]

where \( \Delta Y_t = Y_t - Y_{t-1} \)

\( \varepsilon_t \) = white noise term

The above regression equation (equation 3) includes a drift term \((b_0)\) and a deterministic trend \((a_0)\). Integer p is chosen in equation (3) to achieve white noise residuals for the ADF test and when \(p=0\), the test is known as the Dickey-Fuller (DF) test. Testing the null hypothesis of the presence of a unit root in \( Y_t \) is equivalent to testing the hypothesis that \( H_0: a_1 = 0. \) If \( a_1 \) is significantly less than zero, the null hypothesis of a unit root is rejected. In addition, we test the hypothesis that \( Y_t \) is a random walk with drift, i.e. \( a_0 \) and \( a_1 \) are equal to zero, and \( Y_t \) is random walk without drift i.e. \( b_0 = a_0 = a_1 \) are individually equal to zero. For these three purposes the Tau (\( \tau \)) test statistics are checked against the critical values and the null hypothesis is accepted or rejected if the Tau (\( \tau \))-statistics is greater or less than the critical value respectively. Now if a variable is non-stationary at level and after taking first difference of the variable, it becomes stationary, then the variable is said to be integrated of order one and written as I(1).

The above test can also be carried out for the first difference of the variables. And if the variable becomes stationary after differencing twice, the variable is said to be integrated of order 2 and is written as I(2). In general, a
series is said to be integrated of order \( d \), if the series achieves stationary after differencing \( d \) times, denoted \( Y_t \sim I(d) \).

Cointegration of two or more time series suggests that there is a long-run or equilibrium relationship between them. It implies that in spite of being individually being non-stationary, a linear combination of two or more series can be stationary. Cointegration test is performed to model the dynamic co-independence that is often found in long time series data. Co-integration has emerged as a powerful technique for investigating common trends in multivariate time series and provides a sound methodology for modeling both long run and short run dynamics in the system. In our analysis we use the Engle-Granger testing procedure for testing the presence of co-integration among the auction prices. Suppose \( Y_t \) and \( Z_t \) are two \( I(1) \) variables, Engle-Granger propose a straightforward test whether the two \( I(1) \) variables are co-integrated. The test is carried out in two steps:

**Step 1: Pre-testing the variables for their order of integration.**

Co-integration necessitates that the variables be integrated of the same order. Thus, the first step in the analysis is to pre-test each variable to determine its order of integration. For this we perform the Augmented Dickey Fuller (ADF) Tests which has described earlier.

**Step 2: Estimating long-run equilibrium relationship.**

If both the variables are integrated of same order, the next step is to estimate the long-run relationship of the form:

\[
Y_t = \beta_0 + \beta Z_t + \epsilon_t \quad \text{...............}(7)
\]

To determine if the variables \( Y_t \) and \( Z_t \) are co-integrated, the residual sequence from this equation is denoted as \( \epsilon_t \). Thus \( \epsilon_t \) is a series of the estimated long-run relationship. If these deviations from long run equilibrium are found to be stationary, then \( Y_t \) and \( Z_t \) sequences are co-integrated of order \((1, 1)\).

To test the stationarity of residuals, I’ve applied the ADF test

Cointegration of prices from two different markets would mean that the two markets are integrated. But there can be disequilibrium in the short run meaning that a price change in one market is not immediately passed onto another market. Using Error Correction Methodology (ECM), the short-run and long-run effects of price movements can be incorporated. If two variables \( x \) and \( y \) both are \( I(1) \) and also integrated in the long run, then the error correction model (ECM) for \( x \) and \( y \) is written as

\[
\Delta Y_t = \alpha + \beta \Delta Y_{t-1} + \delta Y_{t-1} + \epsilon_t
\]

where \( \Delta \) stands for first difference operator, \( \epsilon_{t-1} \) is the error which occurs one period lag and \( \epsilon_t \) is the difference term.

Here the hypothesis of strong form of market integration can be performed by testing the restriction \( \alpha = 0 \) and \( \beta = 1 \). On the other hand, the weak form of market integration is tested by the restriction \( \alpha \neq 0 \) and \( \beta = 1 \). The parameter \( \delta \) gives the speed of adjustment.

**RESULTS AND DISCUSSION**

We start with the Correlogram analysis using 130 lags for each of the series of auction prices. The plot of the ACF and the PACF against 130 lags of the respective indices are shown in Figure-1, 2, and 3.

Figure 1: Correlogram Analysis of Potato Price at Chapadanga

![Source: Author’s analysis using Gretl](image1)

Figure 2: Correlogram Analysis of Potato Price at Pandua

![Source: Author’s analysis using Gretl](image2)

Figure 3: Correlogram Analysis of Potato Price at Sheorafuli

![Source: Author’s analysis using Gretl](image3)

The results indicate that the potato prices at all the wholesale markets (Chapadanga, Pandua and Sheorafuli) are non-stationary at levels. The stationarity or non-stationary of the potato prices at different markets can further be confirmed by the Augmented Dickey Fuller Test. The hypothesis of the stationarity analysis can be set as follows:

\( H_0 \) : The selected auction prices have unit roots against \
\( H_1 \) : The selected auction prices are stationary

The result of the Augmented Dickey Fuller test is shown in the table 1.
The potato markets of Hooghly district of West Bengal are integrated and market mechanism play an important role through influencing the price change in one market to another market. Table 3 presents the results of error-correction model for the auction markets. It is evident from the results that the coefficient of error-term are negative and statistically significant, implying that there exists short-run dynamics with the long-run equilibrium. This implies that if any divergence from long-run equilibrium occurs in period (t-1), it will be adjusted towards equilibrium level in period t.

Table 3: Results of Error Correction Model of Auction Markets in India

\[
\Delta \text{Chapadanga} = 0.272 + 0.411 \Delta \text{Pandua} - 0.334 \epsilon_{t-1} \\
(0.625) (12.12) (-2.823)
\]

\[
\Delta \text{Chapadanga} = 0.243 + 0.343 \Delta \text{Sheorafuli} - 0.434 \epsilon_{t-1} \\
(0.553) (11.54) (-2.579)
\]

\[
\Delta \text{Pandua} = 0.181 + 0.344 \Delta \text{Sheorafuli} - 0.387 \epsilon_{t-1} \\
(0.306) (8.467) (-2.279)
\]

Figures in the parentheses are the corresponding t values. Source: Author’s calculation based on Tea Statistics, Tea Board of India

Table 4: Testing for a Strong Form of Integration

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variable</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapadanga</td>
<td>Pandua</td>
<td>F(2, 381) = 150.82</td>
</tr>
<tr>
<td>Chapadanga</td>
<td>Sheorafuli</td>
<td>F(2, 381) = 243.41</td>
</tr>
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Source: Author’s calculation based on Tea Statistics, Tea Board of India

The results of strong form of market integration in tea auction markets are given in table 4. It is seen from the table 4 that the potato markets of Hooghly district do not support the strong form of market integration, as in all the cases the calculated F-value is much higher than the critical value of F-statistic, thereby rejecting the null hypothesis of strong market integration and accepting the weak form of market integration. Thus, it can be said that though the wholesale potato market in Hooghly district are spatially integrated, they appears to be weakly integrated.

The speed of adjustment for different markets is shown in table 5.

Table 5: Speed of adjustment of among selected pairs of auction markets

<table>
<thead>
<tr>
<th>Markets</th>
<th>Pandua</th>
<th>Sheorafuli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapadanga</td>
<td>33.4</td>
<td>43.4</td>
</tr>
<tr>
<td>Pandua</td>
<td>38.7***</td>
<td></td>
</tr>
</tbody>
</table>

** and *** imply significant at 5 % & 10% level of significance respectively. Source: Author’s calculation based on Tea Statistics, Tea Board of India

The adjustment parameter (δ) ranges from 43.4 per cent to 33.4 per cent. The highest speed of adjustment was

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Table 1: Augmented Dickey Fuller Unit Root Test

<table>
<thead>
<tr>
<th>Variables (Auction Prices)</th>
<th>At levels</th>
<th>At first difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With drift and trend</td>
<td>With drift and trend</td>
</tr>
<tr>
<td>Chapadanga</td>
<td>-3.031</td>
<td>-1.960</td>
</tr>
<tr>
<td>Pandua</td>
<td>-2.071</td>
<td>-2.064</td>
</tr>
<tr>
<td>Sheorafuli</td>
<td>-2.315</td>
<td>-2.303</td>
</tr>
</tbody>
</table>

Source: Author’s calculation based on Potato prices, Agmarknet, Govt. of India

Table 2: Engle-Granger Test for Cointegration

<table>
<thead>
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<th>Dependent variable (Auction price)</th>
<th>Independent variable (Auction price)</th>
<th>Engle-Granger test</th>
</tr>
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<tbody>
<tr>
<td>Chapadanga</td>
<td>Pandua</td>
<td>-3.572*</td>
</tr>
<tr>
<td></td>
<td>Sheorafuli</td>
<td>-6.816*</td>
</tr>
<tr>
<td>Pandua</td>
<td>Chapadanga</td>
<td>-3.585**</td>
</tr>
<tr>
<td></td>
<td>Sheorafuli</td>
<td>-4.544*</td>
</tr>
<tr>
<td>Sheorafuli</td>
<td>Chapadanga</td>
<td>-7.045*</td>
</tr>
<tr>
<td></td>
<td>Pandua</td>
<td>-4.61*</td>
</tr>
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* significant at 1 per cent. ** significant at 5 per cent
Source: Author’s calculation based on potato prices, Agmarknet, GOI.

Engle-Granger test results show that wholesale potato prices at Chapadanga were found to be dependent on Pandua and Sheorafuli wholesale prices. Hence it could be said that wholesale prices of potato at Chapadanga market were adjusted to any price change in the Pandua and Sheorafuli markets, i.e., Chapadanga prices appeared to be having market efficiency. Similarly, pairwise combinations of Pandua-Chapadanga, Pandua-Sheorafuli, Sheorafuli-Chapadanga and Sheorafuli-Pandua gave significant estimates implying that the auction prices of potato were spatially integrated. Thus, it appears that the potato prices of all the wholesale markets in the Hooghly district are cointegrated and it implies that the price movement in one market is passed onto all other markets in bidirectional ways.

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The adjustment parameter (δ) ranges from 43.4 per cent to 33.4 per cent. The highest speed of adjustment was
observed between the wholesale markets of Chapadanga and Sheorafuli. This implies that if any divergence appears from the long-run equilibrium, it will be adjusted towards the equilibrium value by the speed of 43.4 per cent.

CONCLUSION AND POLICY IMPLICATIONS

Using time series econometrics methods, the present study made an attempt to examine the price behaviour and the extent of market integration of the three major wholesale potato markets in the country. In the cointegration set up, error correction method estimates the long-run relationship between the auction prices as well as fluctuations in the short-run.

The results show that the three major markets of the district viz. Chapadanga, Pandua and Sheorafuli seem to be spatially integrated. However, the markets are not strongly cointegrated; rather they are weakly cointegrated. This is mainly due to close proximity, good transport and communication system and good marketing infrastructure across the marketing centers of the district. The high degree of market integration implies that the wholesale potato markets in the district are competitive and efficient enough to transmit the price signals across all the marketing channels. However, my study does not consider the analysis of farm level market where the potato producers have direct link with the traders. In this situation, it is generally argued that the development of infrastructural facilities in terms of transport and network communication at the very grass root level, which will bring an early flow of information about the demand, supply and price to and from various markets, is the utmost necessary to take the advantage of globalization. These will help in increasing market integration and efficiency of potato markets at the village level also.

REFERENCES