Spatial Market Integration of Arhar (Split) Wholesale Prices in India : Application of Vector Error Correction Model

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Abstract

The present study aimed at analysing the spatial market integration of arhar markets in India, based on the monthly wholesale prices of arhar (split) in Mumbai (Maharashtra), Hyderabad (Telangana), Chennai (Tamil Nadu), and Bangalore (Karnataka) markets for the period from January 2011 to December 2015. The Augmented Dickey Fuller test indicated that Mumbai, Chennai, and Hyderabad arhar market price series were *I*(1), but that of the Bangalore arhar market, the price series were *I*(2) ; hence, further analysis was carried out for these three markets only. The results of Johansen co-integration test indicated that three arhar markets were significantly co-integrated with each other. The VECM model revealed that speed of adjustment for Mumbai and Hyderabad markets was statistically significant, but for Chennai market, it was insignificant, though having an expected negative sign. The Granger causality test indicated unidirectional relationship between the markets. The speed of price transmission was slow for all the three markets. This may be due to reasons such as lack of proper infrastructural facilities, paucity of institutional arrangements, transport costs, and absence of good government policies. This calls for more efforts on the part of the government in removing these constraints so that there will be efficient flow of price information among the domestic arhar markets in India.

Keywords : **stationarity, co-integration, error correction model, Granger causality**

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Pigeonpea (arhar) also popularly known as tur or red gram is the second most important pulse crop (next to chickpea) grown in India. It is mainly consumed in the form of split pulse as dal. It occupies 12% of the total pulse area and 17% of the total pulse production in the country (Tiwari & Shivhare, 2016). It is an important source of protein to the vegetarian population of the country and also provides feed to the livestock. Being a legume crop, it plays a pivotal role in sustainable agriculture. The per capita availability of Pigeonpea in the country is unable to meet the per capita demand which is showing an increasing trend due to rising income levels of the people and population increase.

Despite being the largest producer, India is importing Pigeonpea, which is showing an increasing trend over the years. This puts pressure on our forex reserves. Hence, there is a need to increase the area under cultivation for the crop. However, this can be possible if producers get remunerative prices for the product which acts as an incentive for the farmers to enhance land allocation under the crop. This necessitates that the arhar markets are integrated throughout the country so that increase in the price of arhar in one market will motivate the upward change in the other arhar markets. This means arhar markets are to be co-integrated so that there will be effective transmission of price signals across markets. This will also improve the producers' and consumers' welfare. Given the importance of the crop and growing demand for the product by the people, it is essential to understand to what extent arhar (split) markets are co-integrated so that the information is useful in making appropriate agricultural policies for the

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management of agricultural risks related to different variables, especially agricultural prices, which are crucial in decision making in the agriculture sector. Hence, the present study analyses the degree of spatial domestic arhar market integration among four South Indian markets, mainly Maharashtra, Karnataka, Telangana, and Tamil Nadu with the help of Johansen co-integration test, vector error correction model (VECM), and Granger causality test.

Review of Literature

The study of spatial market integration mainly aims at understanding the existence of, if any, long run association among the different economic variables, if there exists long run equilibrium, then it further analyses the long run and short-run dynamics involved in it and the type of causal effects between the variables. There exists huge literature on market integration and price transmission pertaining to numerous commodity markets. Some of the recent works done by the researchers in the field are discussed here. Spatial market integration analysis for cotton markets in India was analysed by applying vector error correction model (VECM), and the analysis indicated that all the market pairs exhibited bi-directional causality, and prices were transmitted effectively, signalling that mutual influence was exerted by the domestic cotton markets on each other (Bhavani Devi, Srikala, Ananda, Subramanayam, &Venkatesu, 2015). The study on the spatial integration of domestic markets for papaya in Ethiopia was done with the help of Johansen co-integration test, VECM, and Granger causality test using 13 years average monthly prices (Habte, 2017). The VECM test indicated that the error correction term was significant at the 1% level, signalling higher speed of adjustment for the Arbaninch market compared to other papaya markets. The Granger causality test showed that price for papaya in Arbaninch market had bidirectional relationship with papaya prices in Merkato and Shashemenie markets, and based on the results, the author suggested the need on the part of the government agencies to address the low degree of price adjustment between various papaya markets in Ethiopia.

Jena (2016) examined the commodity market integration and price transmission using the techniques of co-integration and VECM. The author found that there existed both short-run and long-run relationship between domestic commodity index prices and international commodity index prices. The study concluded that the integration of agricultural commodities was weak in India, and the major reason for this was the excessive government intervention. The analysis of spatial integration of maize markets in Nigeria was done based on VECM, and the results showed that the spatial price linkages existed between maize markets in Nigeria, and the study emphasized the need of mechanism for effective dissemination of the price information among farmers in order to take advantage of spatial price differences (Ilkudayisi & Salman,2014). A study on testing the existence of association between 14 stock markets of the different countries was done using various tools like correlation, Granger - causality tests, and Johansen COI, and results showed ample evidence of existence of long run association among the selected stock markets (Patel, 2017).

BRICS stock markets' integration had been tested with the help of Johansen COI for testing the long run association and results of trace test and maximum Eigen value test indicated the existence of one co-integrating relationship among the selected stock markets (Aggarwal &Khurana, 2018). Based on the results, the authors suggested that investing in different stock markets was beneficial to the investors. Similarly, a number of studies have been conducted by the researchers on the market integration of various agricultural commodities in India using Johansen co-integration test, VECM, and Granger causality tests (Ajjan, Shajeena, & Raveendaran, 2013 ; Burark, Sharma, & Meena, 2013 ; Kaur & Sekhon, 2016 ; Paul, Das, Debnath, & Mathur, 2017 ; Vasudev,Vijaya Kumari, Gundu, Kireeti, & Panasa, 2015) and it may be inferred from the literature review that inefficient marketing practices affect adversely the producers' and consumers' social welfare. The present study employs the ADF test, Johansen co-integration test, VECM, and Granger causality test to test the spatial market integration among southern arhar (split) market prices in India.

Research Methodology

(1) Sources of Data : The present study intends to analyse the market integration and adjustment of arhar (split) prices among domestic markets in India. The study is restricted to four Southern markets mainly, Mumbai (Maharashtra), Bangalore (Karnataka), Chennai (Tamil Nadu), and Hyderabad (Telangana). Based on the availability of data and volume of transaction of tur, the study selected these four markets for the analysis. The monthly wholesale prices of arhar (split) for these four markets were collected from Centre for Monitoring Indian Economy (CMIE) data source for the period from January 2011 to December 2015.

(2) Methods of Analysis : To analyze the degree of market integration across these Southern markets for arhar (split),various econometric tools like augmented Dicky Fuller (ADF) test for testing the stationarity of the time series data, Johansen's co-integration test to test the presence of long run association among the markets, and vector error correction model (VECM) to analyze the integration of markets across different locations were employed in the present study. E-views 9 software package was used to carry out the econometric analysis.

The time series analysis requires that the series under consideration must be stationary prior to carrying out any type of analysis for the series. Hence, my first task begins with the testing for stationarity of the series under consideration. Time series are said to be stationary if their parameters like mean, variance, and covariance are time invariant. If the series under consideration are non-stationary, then they have to be made stationary with the suitable transformation of the series. In such cases, series differenced once will be tested for stationarity. The number of times a series needs to be differenced in order to make it stationary is known as the order of integration and symbolically, it is written as *I(d),* where *I* stands for integration and *d* for the number of times a series is differenced. The ADF test is estimated in three different forms (Gujarati & Sangeeta, 2007).

$\Delta Y_t = \delta Y_{t-i} + \Sigma\alpha\Delta Y_{t-i+1} + U_t$: a random walk ------------------------(1)

$\Delta Y_t = \beta_1 + \delta Y_{t-i-1} + \Sigma\alpha\Delta Y_{t-i+1} + U_t$: a random walk with drift ------------------(2)

$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-i} + \Sigma\alpha\Delta Y_{t-i+1} + U_t$: random walk with drift around a stochastic trend ------------------(3)

The lag length of the model is selected based on the Schwartz information criteria (SIC) and Akaike information criteria (AIC) criteria. Null hypothesis is H_0: $\delta = 0$, that is, the time series is non - stationary against alternative hypothesis $H_1 = \delta < 0$,that is, the time series is stationary. After the series are tested for stationarity, and they are integrated of the same order, integration between the series will be tested using Johansen test. Johansen co-integration (COI) test determines the number of co-integrating relationships among the non-stationary time series using the maximum likelihood method (MLM). In order to understand the Johansen COI test, we have to consider the vector auto regressive (VAR) model of order *p* as mentioned below (Paul et al., 2017) :

$x_t = A_1 x_{t-1} + A_2 x_{t-2} + A_3 x_{t-3} + ------ A_p x_{p-1} + \varepsilon_t$ ------------------------(4)

x_t is $(n \times 1)$ vector $(x_{1t}, x_{2t}, x_{3t}, ..., x_{nt})'$, ε_t is an independently and identically distributed *n* - dimensional vector with mean zero and a constant variance. The reduced form of the above equation may be written as follows :

$x_{it} = \Sigma^{p}_{i=1} \Pi\Delta x_{t-i} + \mu + \beta t + e_i$ -------------------------- (5)

The Johansen's model can be expressed as follows (Paul et al., 2017) :

$\Delta x_t = \Sigma^{p-1}_{i=1} \Pi\Delta x_{t-i} + \Pi x_{t-p} + \in_t$ -------------------------- (6)

where,

$$\pi = -(I - \Sigma^{p}_{i=1} A_i) \ \& \ \pi_i = -(I - \Sigma^{i}_{j=1} A_i)$$

The coefficient matrix π provides long run co-integrating relationships. In Johansen's procedure, lag length has been determined based on SIC and AIC processes. Johansen provides two test statistics for co-integration, trace test and the maximum Eigen value test.

$$\lambda_{trace}(r) = -T\, i = r + \Sigma^{n}_{i=r+1}\, ln = -(1-\lambda_i) \text{ --------------------------- } (7)$$

$$\lambda_{max}(r, r+1) = -T\, ln\, (1 - \lambda_{r+1}) \text{ --------------------------- } (8)$$

where, T = number of observations, λ = number of non- zero Eigenvectors,
r = number of co-integrating vectors under the null hypothesis.

Under trace test :
$H_0 : r = 0$ (no co-integrating vectors) against $H_1 : r \geq 0$ (co-integrating vectors)

Under maximum Eigen value test:
H_0 = Number of COI vector = r against H_1 = Number of COI vectors = $r+1$ (Paul et al., 2017).

If the trace test and maximum Eigen value statistic reveal the presence of a long term relationship between time series data, then the error correction mechanism (ECM) can be applied to test the short run properties of the co-integrated series. If two or more variables are integrated of order 1, then vector error correction model (VECM) can be used which includes variables in levels and first difference. The VECM can be written as follows (Habte, 2017) :

$$\Delta x_t = \mu + \Sigma^{n}_{i=1} \beta_i \Delta y_{t-i} + \Sigma^{n}_{i=1} \gamma_i \Delta x_{t-i} + \varphi ECT_{t-1} + \varepsilon_t \text{ ------------------}(9)$$

Analysis and Results

(1) Stationarity Test : The first and foremost task of time series data analysis is to check for the stationarity of the series for all the selected arhar market wholesale prices based on the ADF test. All the price series are transformed into natural logarithms. The results of the ADF test are presented in the Table 1.

Table 1. Unit Root Test Results for Arhar (Split) Prices

Price of Arhar (Split)/Market (State)		ADF Test Statistics	*P- values	Stationary/ Order of Integration
Mumbai	At Levels	1.0555	0.9967	No / I(0)
(Maharashtra)	At First Difference	-7.5482	0.0000	Yes / I(1)
Hyderabad	At Levels	1.2314	0.9980	No / I(0)
(Telangana)	At First Difference	-7.4859	0.0000	Yes / I(1)
Chennai	At Levels	0.9021	0.9949	No / I(0)
(Tamil Nadu)	At First Difference	-7.9805	0.0000	Yes / I(1)
Bangalore	At Levels	4.5951	1.0000	No / I(0)
(Karnataka)	At First Difference	-2.1494	0.2268	No / I(1)
	At Second Difference	-19.75482	0.0001	Yes / I(2)

Note :Data are in Natural log form ; Null Hypothesis H_0 = The series has a unit root.

* MacKinnon (1996) one - sided p- values.

The lag length was selected based on the AIC and BIC criteria. Unit root results reveal that none of the arhar (split) price series are stationary at levels as we fail to reject H_0, but the price series at Mumbai, Hyderabad, and Chennai markets are made stationary at first difference and that of Bangalore market price series at second difference. So, wholesale prices of arhar (split)at Mumbai, Hyderabad, and Chennai are integrated of order $I(1)$ and for Bangalore, the market price series are integrated of order $I(2)$.

(2) Johansen Co-integration Tests : The precondition for application of Johansen co-integration test is that all the price series must be integrated of the same order. In the present case, arhar (split) wholesale prices at Bangalore market are integrated of order $I(2)$ compared to other three markets prices which are integrated of the same order, that is, $I(1)$. Hence, Johansen co-integration test is applied to three markets, mainly Mumbai, Hyderabad, and Chennai to understand the presence of the long run relationship between these domestic markets. The optimal number of lags to include in the vector auto regressive (VAR) model is based on the AIC, BIC, and Hannan-Quinn criteria (HQC). The Johansen co-integration procedure involves two tests namely trace statistics and maximum Eigen value statistics. The results of the Johansen co-integration tests are presented in the Table 2 and Table 3 for trace and maximum Eigen value statistics, respectively.

The Table 2 clearly indicates that as per the trace test results, there exist two co-integrating equations, which is confirmed by the rank test (Table 3). The results show that the wholesale price series of arhar (split) in Mumbai, Hyderabad, and Chennai markets are co-integrated and there exists long run equilibrium relationships between these three arhar (split) market prices in India.

(3) Vector Error Correction Model (VECM) : Johansen co-integration test indicates that there exists long run relationship among three arhar markets namely Mumbai, Hyderabad, and Chennai. This result takes us to test whether there exists any short run relationship between these three markets. In order to examine the short run relationship between these three domestic arhar markets, VECM is employed. The optimum lag selection for VECM is done on the basis of AIC, SIC, and HQC criteria. The estimated VECM results are presented in the Table 4.

Table 2. Johansen Co-Integration Rank Test (Trace) Results for Three Arhar (Split) Market Prices

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.335974	42.07414	29.79707	0.0012
At most 1 *	0.246683	18.32697	15.49471	0.0182
At most 2	0.032183	1.897326	3.841466	0.1684

Note :Trace test indicates two co-integrating equations at the 0.05 % level.
*denotes rejection of the null hypothesis at the 0.05% level.
**MacKinnon-Hauq-Michelis (1999) *p*-values.

Table 3. Johansen Co-Integration Rank Test (Maximum Eigen Value) Results for Three Arhar Market Prices

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistics	0.05 Critical Value	Prob.**
None *	0.335974	23.74717	21.13162	0.0209
At most 1 *	0.246683	16.42965	14.26460	0.0224
At most 2	0.032183	1.897326	3.841466	0.1684

Note :Maximum-Eigen value indicates two co-integrating equations at the 0.05 % level.
*denotes rejection of the null hypothesis at the 0.05% level.
**MacKinnon-Hauq-Michelis (1999) *p*-values.

Table 4. Results from the Vector Error Correction Model

Error Correction:		*D(LN MUM)*	*D(LN HYD)*	*D(LN CHEN)*
Coint Eq1		-0.064601***	-0.077570***	-0.020082
[ECM(-1)]	Standard Error	(0.02043)	(0.01866)	(0.01962)
	t-value	**[-3.16250]**	**[-4.15727]**	[-1.02345]
D(LN MUM (-1))		-0.071736	-0.055151	-0.325462**
	Standard Error	(0.13235)	(0.12090)	(0.12714)
	t-value	[-0.54201]	[-0.45619]	**[-2.55991]**
D(LN HYD (-1))		0.268557*	-0.040617	0.214223
	Standard Error	(0.15683)	(0.14325)	(0.15065)
	t-value	**[1.71243]**	[-0.28354]	[1.42200]
D(LN CHEN (-1))		-0.443328**	-0.105573	-0.197122
	Standard Error	(0.19129)	(0.17473)	(0.18375)
	t-value	**[-2.31762]**	[-0.60422]	[-1.07278]
C		0.014725	0.018313	0.014913
	Standard Error	(0.00806)	(0.00736)	(0.00774)
	t-value	[1.82755]	[2.48812]	[1.92680]

***,**,* implies rejection of H_0 at 1%, 5%, and 10% level of significance, respectively.
MUM: Mumbai Market Prices (Maharashtra); HYD: Hyderabad Market Prices;
CHEN: Chennai Market Prices (TN)

The estimated VECM results reveal that error correction coefficients for arhar (split) prices have the expected negative sign and have value less than one for all the three markets and they are significant at the 1% level for Mumbai market of Maharashtra and Hyderabad market of Telangana and insignificant for Chennai market of Tamil Nadu. The error correction coefficient measures the speed of adjustment of arhar (split) prices towards long run equilibrium. The estimated error correction coefficient values indicate that 6.46% and 7.76% of the disequilibrium in the long run got corrected within a month as a result of shocks in their own prices in case of Mumbai and Hyderabad markets, respectively. The other market forces influence the remaining part of the disequilibrium. In case of the Chennai market, 2% of the disequilibrium got corrected within a month. The results also reveal that arhar (split) price movements in Mumbai (Maharashtra) are greatly influenced by the price changes in Hyderabad (significant at 10%) and Chennai (significant at 5%) arhar markets. It means price discovery occurs in the markets and it was transmitted to the Mumbai market. Price movements in Chennai market of Tamil Nadu are influenced by one month lagged prices of Mumbai market (significant at 5% level) of Maharashtra. So, price discovery occurs in the market and it was transmitted to Chennai market ; 44% and 27% of the disequilibrium in the Mumbai market got corrected by the one month lagged arhar (split) prices in Hyderabad and Chennai markets, respectively, and 32% of the disequilibrium in the Chennai market got corrected by the one month lagged arhar (split) prices in the Mumbai market.

To understand the direction of causation between the selected arhar (split)market prices, the Granger causality tests were adopted. The Granger causality test enables us to understand the influence of price of each market on all other markets in the study. The optimal lag length was selected based on the AIC and BIC criteria. The results of the same are presented in the Table 5. The results in Table 5 indicate that there is unidirectional causality between Hyderabad and Mumbai markets, Chennai and Mumbai markets, and Chennai and Hyderabad markets.

This means Hyderabad and Chennai markets Granger cause price formation in the Mumbai arhar (split) market, but Mumbai market does not provide feedback to Hyderabad and Chennai arhar markets. Similarly, the Chennai

Table 5. Pair Wise Granger Causality Test

Null Hypothesis	*F*-Statistic	Probability	Direction of Price Movements
HYD (TEL) does not Granger cause MUM (MAH)	17.4483	0.0001	→
MUM (MAH) does not Granger cause HYD (TEL)	0.04600	0.8309	
CHEN (TN) does not Granger cause MUM (MAH)	15.3571	0.0002	→
MUM (MAH) does not Granger cause CHEN (TN)	0.06329	0.8023	
CHEN (TN) does not Granger cause HYD (TEL)	17.4002	0.0001	→
HYD (TEL) does not Granger cause CHEN (TN)	0.13139	0.7184	

market depends on the Hyderabad market for price information, but the Hyderabad market does not depend on the Chennai market to fix its arhar (split) price. The results indicate that mutual influence is not exerted by the arhar (split) markets on each other.

Conclusion and Policy Recommendations

The present study aimed at investigating the spatial market integration among arhar (split) markets, degree of price transmission among the selected markets, and the direction of causality between arhar (split) markets in India. For this purpose, econometric techniques like ADF stationarity test, co-integration, VECM, and Granger causality tests were employed. The ADF tests suggest that price series in Mumbai, Hyderabad, and Chennai markets are integrated of order one, that is, $I(1)$, but that of Bangalore market, the prices are $I(2)$. Hence, the analysis of co-integration was carried out for the three markets - Mumbai, Chennai, and Hyderabad. Johansen's trace and maximum Eigen value tests indicate that there exists long run association between the three arhar (split) prices. The error correction term (ECT) estimated by VECM shows that around 7% and 8% of the disequilibrium in the Mumbai market of Maharashtra and Hyderabad market of Telangana got corrected within a month by changes in its own prices, respectively (ECT are significant). The remaining part of the disequilibrium was corrected by the internal and external sources. In case of the Chennai market of Tamil Nadu, 2% of the disequilibrium got corrected within a month, though the ECT is having expected negative sign, but it is insignificant. Long run price movements of the Mumbai market are greatly influenced by the Hyderabad and Chennai market prices.

The speed of price transmission is slow for all the three markets, but it is insignificant in case of the Chennai market. This may be due to a number of reasons such as lack of proper infrastructural facilities, paucity of institutional arrangements, costs of transportation, inaccurate price transmission, and need of proper government policies. All these resulted in inefficient transmission of arhar (split) prices among different domestic markets, which in turn affect the farmers adversely as they are denied the opportunity of getting proper remuneration for their products. This calls for more efforts on the part of the government in creating better infrastructure facilities, proper institutional arrangements, and favourable policy environments so that there will be efficient flow of price information among domestic arhar markets in India.

Limitations of the Study and Scope for Further Research

The present study focused on analyzing the market integration aspect of the arhar prices in Southern Indian markets only. Secondly, the analysis revealed that the price information transmission among different markets is low, signalling the interplay of many other factors. It is necessary to study the influence of the other various factors as discussed above to understand the reasons for weak market integration among domestic arhar (split) markets.

Hence, there is need for further research in this direction. Further research may be required in this aspect at the macro level involving all the important arhar markets in the country.

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