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Analysing Market Integration and Causality of Oilseed Crops: Key Insights and Challenges in Major Tamil Nadu Markets and Interstate Regions of India

Gowri Shankar [a++] and A. Malaisamy [a#*]

[a] *Department of Agricultural Economics, Agricultural College & Research Institute, Madurai, Tamil Nadu, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Oilseed crops like Sesame and Groundnut experience significant price fluctuations due to factors like seasonal production patterns, their perishable nature, and risk involved in production and marketing of output. The farmers are further complicated by a lack of information about market conditions, including the timing of arrivals and prices. Market integration, which helps stabilize prices and improve the efficiency of the marketing system. This study focuses on analysing the

[++] *Research Scholar;*
[#] *Professor and Head;*
**Corresponding author: E-mail: malaisamy@tnau.ac.in;*

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market integration of major oilseed crops— Sesame, and Groundnut in India from January 2013 to January 2024. Johansen's cointegration test and Granger Causality test were applied to examine how prices in different markets are influence one another. The stationarity of the prices tested using the Augmented Dickey-Fuller test. The results confirmed that the prices are cointegrated, showing a strong interdependence between them. The analysis also revealed causal relationships between regions, such as bidirectional causality in the case of Sesame and Groundnut. The findings underscore the importance of further research to address production challenges, improve technical methods, and develop informed policies to manage the issues faced by oilseed crop growing farmers. This will help overcome obstacles in production and ensure a more efficient marketing system.

Keywords: Groundnut; sesame; granger causality; market integration.

1. INTRODUCTION

India has been grappling with a chronic shortage of edible oils due to insufficient domestic oilseeds crop production, even though it briefly achieved self-sufficiency during the “Yellow Revolution” in the early 1990s. India is the fourth largest oilseed producing country in the world, next only to USA, China and Brazil. Indian share in world production of oilseeds has been around 10 percent [1]. The consumption of vegetable oil has significantly increased in recent years for both food and industrial uses, widening the gap between supply and demand. Over the past thirty years, India’s oilseed sector has seen considerable fluctuations, transitioning from a net importer in the 1980s to a short-lived net exporter status in 1989-90, and become net importer by 1997-98. The study of Ali et al. in [2] also implied that India is one of the major importers of edible oils. This shift necessitated a large foreign exchange expenditure to satisfy domestic needs. In India, Tamil Nadu particularly faces a significant challenge in predicting edible oilseed crop prices. Given that 72% of oilseed cultivation is rainfed and high-risk, there is an urgent need to address production, marketing, and price risks to boost productivity and lesser reliance on imports [3,4]. On a global scale, oilseed production, led by soybeans, is on the rise, while other oilseeds are declining. In 2021-22, total production reached 632.86 million metric tons. India is the second largest producer of oilseeds after food grains, but there is a significant gap between domestic production (9.5 million tonnes) and consumption (22.5 million tonnes), leading to a USD 13.5 billion import bill [5,6].

This imbalance contributes to India’s trade deficit, especially in edible oils, which contrasts with its surplus in most other agricultural products. The trade deficit from edible oil imports jumped from USD 8 billion before the pandemic to USD 13 billion in Jan-Oct 2021 [7-9]. The share of edible oil in the total trade deficit nearly doubled from 5.9% in Jan-Oct 2019 to 10% in the same period in 2021. The yield of oilseeds in India is not consistent across the country. The government of Tamil Nadu was recognized for its oilseed production and received the Krishi Karman award (Ministry of Agriculture and farmers welfare, 2019) [10]. If the average yield in India could be increased to match that of Tamil Nadu, the total oilseed production in the country would see an increase of 82%. Tamil Nadu is a significant contributor to this sector, with 40% of the total area under groundnut crop [11-14]. The Tamil Nadu government is promoting the cultivation of high-yield oilseed crops like groundnut, gingelly, sunflower, soybean, and castor. They are encouraging cluster demonstrations and the cultivation of oilseeds in rice-fallow conditions. In 2024, Agriculture budget of Tamil Nadu proposed that former demonstration would be covering an area of 2.5 lakh acres with an outlay of ₹45 crore, funded by both the Union and State governments. To increase the cultivation area and productivity of gingelly in districts declared as the ‘Oilseed Zone’, Rs. 3 crores would be allocated to provide subsidies for inputs and harvesting charges for 25,000 acres [15,16]. The objective is to study the growth and instability of the area, production, and productivity of the oilseed crop in India, assess the price transmission in oilseeds markets in India and Tamil Nadu, and forecast the price of edible oilseeds crop in Tamil Nadu.

2. MATERIALS AND METHODS

The longitudinal wholesale price series data of sesame and groundnut for the current study is collected from secondary source like AGMARKNET. In major oilseed markets are selected based on leading producing and marketing areas as in Directorate of Oilseeds Development (Ministry of Agriculture and Farmer Welfare, 2024) and past studies [17,18], (Mithya et al., 2021), [19] for Sesame, the markets selected are Sivagiri (Erode), Thindivanam (Villupuram), Viruthachalam (Cuddalore) and Attur (Salem); in case of Groundnut, markets include Thindivanam (Villupuram), Punjaipuliyampatti (Erode), Sevur (Coimbatore) and Vellore. The inter-state markets for Sesame the selected markets are Thindivanam (Tamil Nadu), Kalbargi (Karnataka), Gondal (Gujarat); the major markets for Groundnut are Thindivanam (Tamil Nadu), Amreli (Gujarat), Adoni (Andhra Pradesh) were selected for the period from January 2013 to January 2024.

2.1 Johansen Cointegration Test

The concept of cointegration, introduced by Granger [20], along with the methods for estimating a cointegrated relation or system proposed by Engle and Granger [21] and Johansen (1988, 1991, 1995), provide a framework for estimating and testing for long-term equilibrium relationships between non-stationary integrated variables. Time series data are often non-stationary, and if regressed, can yield misleading results. The first step in dealing with time series data is to test for the presence of a unit root in each individual time series of the model. The Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981), both with and without a deterministic trend, is used for this purpose. The number of lags in the ADF equation is chosen to ensure that serial correlation is absent, using the Breusch-Godfrey statistic (Greene, 2000).

The ADF equation is estimated using the Ordinary Least Squares (OLS) method as follows:

Fig. 1. Selected markets for sesame and groundnut crops in India

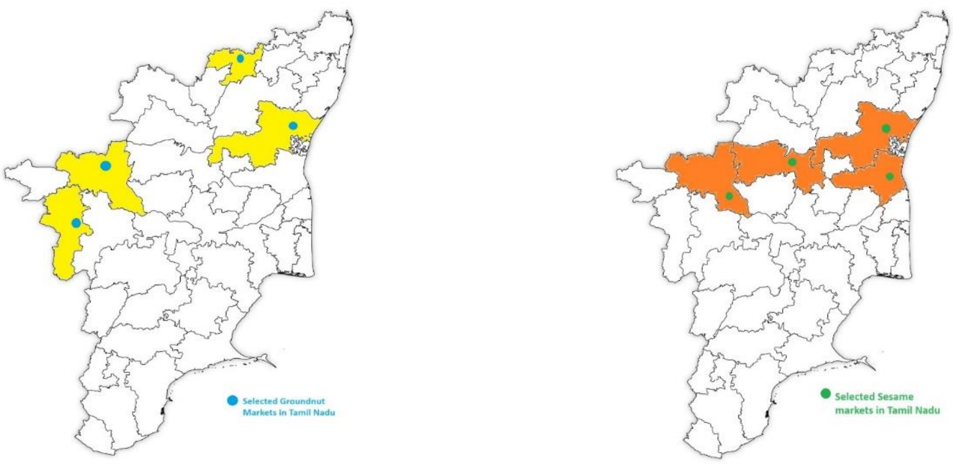

Fig. 2. Selected markets for sesame, and groundnut crops in Tamil Nadu

$$\Delta P_t=a_3+b_3t+(\phi_3-1)\ P_{t-1}+\sum\theta_t\ \Delta P_{t-1}+\mu_t \quad (1)$$

Here, Pt is the series under investigation and μt is the error term. If two series are integrated of the same order, Johansen's (1988) procedure can be used to test for the long-term relationship between them.

The approach adopted in this paper is based on Sims' (1980) methodology of a general unrestricted Vector Autoregressive (VAR) model where, unlike single equation methods, the exogeneity of one price is not imposed ex ante. Long-run market integration is examined using Johansen's cointegration procedure. The VAR model is represented as:

$$X_t=\delta+A1X_{t-1}+A2X_{t-2}+\ldots+A_{p-1}X_{t-p+1}+\varepsilon t \quad (2)$$

In this model, Xt is an (n×1) vector of endogenous variables, δ is an (n×1) vector of parameters, Ai represents (n×n) matrices of parameters, and εt is an (n×1) vector of random variables. The price series for the ten major mango markets were endogenous variables and as such no exogenous variable was used. To test the hypothesis of integration and cointegration in equation (2), it is transformed into its Vector Error Correction form:

$$\Delta Xt=\mu+\pi 1\Delta X_{t-1}+\pi 2\Delta X_{t-2}+\ldots+\pi k-1\Delta X_{t-k+1}+\pi X_{t-k}+\varepsilon t \quad (3)$$

Here, Xt= [P1t, P2t]′ is a vector of endogenous variables, which are I(1), ΔXt=Xt−Xt−1, μ is a (2×1) vector of parameters, π1,…,πk+1 and π are (2×2) matrices of parameters.

Akaike Information Criterion (AIC):

Let *k* be the number of estimated parameters in the model. Let L' be the maximized value of the likelihood funnction for the model, n is the number of data points in the sample.

$$AIC = 2k-2\ \ln(L')$$

Schwarz Based Criterion (SBC):

$$BIC = \ln(n)k - 2\ln(L)$$

2.2 Granger causality Test

To test the pattern of causality between two markets, F test was used. The null hypothesis Hp: The lagged X does not granger Y and the Alternative hypothesis HI: The lagged X granger cause Y [20].

We can test for the absence of Granger causality by estimating the following VAR model:

$$yt = \alpha 0 + \alpha 1 yt-1 + \cdots + \alpha p yt-p + \beta 1 xt-1 + \cdots + \beta p xt-p + \epsilon t$$
$$xt = \alpha 0 + \alpha 1 xt-1 + \cdots + \alpha p xt-p + \beta 1 yt-1 + \cdots + \beta p yt-p + ut$$

For all possible pairs of (x, y) series in the group.

Here F statistic must be used in combination with the p value when deciding about the significance of the results. If p value is less than the alpha level, individual p values are studied to find out which of the individual variables are statistically significant.

3. RESULTS AND DISCUSSION

3.1 Cointegration

After testing the unit root and lag length is determined, the next step is to find out whether the variables share a common stochastic trend, i.e. to test whether two or more variables are co integrated or not. The concept of cointegration implies that if there is a long run relationship between two or more non-stationary variables, deviations from this long-run path are stationary. Johansen's cointegration multivariate procedure is used to establish whether the variables are co-integrated in the long run. The result of likelihood ratio indicates one co-integrating equations at 5% significance level. In other words, it accepts alternative hypothesis of having one co-integrating vector. Since the calculated trace statistic is greater than the 95% critical value of the trace statistic value, it is possible of cointegration exist between the markets for groundnut and sesame. The result for maximum Eigen value test confirms the rejection of the null hypothesis; i.e., no co-integrated vectors. Therefore, both Trace statistic value and maximum Eigen value indicate that there are one co-integrating equations at 5% significance levels as shown in Table 1.

Results from the table presents the estimates of Johansen's Cointegration Test for the selected oilseed markets, focusing on both interstate and intrastate regions for Groundnut and Sesame. The results indicate that for Groundnut, both the interstate and intrastate markets exhibit significant

Table 1. Estimates of Johansen cointegration test for oilseeds crop

Markets	Hypothesised No. of CE	Trace Statistic	Eigen Value	Prob
Groundnut (Interstate)	None**	56.22**	0.26**	0.0002
	At most 1	20.77	0.15	0.0073
Groundnut (Intrastate)	None**	105.39**	0.34**	0.0002
	At most 1	55.05	0.22	0.0052
Sesame (Interstate)	None**	41.12	0.19	0.0102
	At most 1	15.64	0.11	0.1916
Sesame (Intrastate)	None**	0.15**	0.17**	0.0042
	At most 1	19.91	23.31	0.5048

***denotes rejection of the hypothesis at the 5% level*

cointegration, as seen by the rejection of the null hypothesis at the 5% Vellore, with trace statistics of 56.22 and 105.39, respectively. In the case of Sesame, the intrastate markets demonstrate cointegration, while the interstate markets show weaker evidence, with the interstate markets' trace statistic of 41.12 not reaching the same level of significance as other crops. Overall, these findings suggest a strong interdependence and long-term equilibrium relationship among the selected oilseed markets, particularly in Groundnut.

3.2 Granger Causality Test for Different Oilseed Crops

3.2.1 Groundnut

Granger causality is also estimated between pairs of domestic groundnut markets in India. Granger causality means the direction of price formation between six markets and related spatial arbitrage, i.e., physical movement of the commodity to adjust for these prices differences.

Unidirectional flow states that change in price of one market will influence the other market, whereas bidirectional is defined as change in price of one market influence the other market and vice versa. The unidirectional causation found between Coimbatore and Erode (i.e., Erode does not Granger cause Coimbatore, but Coimbatore Granger causes Erode). This means that Erode's price changes may be predicted by Coimbatore, but not the other way around. In the same way, price of groundnut in Thindivanam market is influenced by Adoni market and not vice-versa Two markets can exhibit bidirectional causality, which implies that they have reciprocal impact when they forecast one another [22]. The findings show that Granger causality is bidirectional, which means the changes in one market's price may influence on other market and vice versa. Vellore and Thindivanam exhibits bidirectional causality. Connections that are bidirectional frequently imply a close connection in which the price dynamics of the two marketplaces are influenced by one another.

3.2.2 Sesame

Table 3 provides the Granger causality test results for Sesame markets, both within (intrastate) and across (interstate) states. The test identifies significant unidirectional and bidirectional causality between markets, indicating how price movements in one market can influence others. These relationships highlight key patterns of market integration and interdependence among Sesame-growing regions.

Results from the Table 3 summarizes the Granger causality test for Sesame markets at both the intrastate and interstate levels. In the intrastate markets, significant unidirectional causality is observed between Cuddalore and several markets. For instance, Cuddalore Granger-causes both Salem (p = 0.0039) and Villupuram (p = 0.0007), while Erode

Table 2. Results of granger causality test for groundnut

Null Hypothesis	F- statistics	Prob.	Reject H0
Groundnut Intra-state			
ERODE does not Granger Cause COIMBATORE	1.95300	0.1466^{NS}	Accept
COIMBATORE does not Granger Cause ERODE	3.58753	0.0309**	Reject
THINDIVANAM does not Granger Cause COIMBATORE	1.77698	0.1738^{NS}	Accept
COIMBATORE does not Granger Cause THINDIVANAM	0.05276	0.9486 ^{NS}	Accept

Null Hypothesis	F- statistics	Prob.	Reject H0
VELLORE does not Granger Cause COIMBATORE	1.99314	0.1410 NS	Accept
COIMBATORE does not Granger Cause VELLORE	0.13922	0.8702 NS	Accept
THINDIVANAM does not Granger Cause ERODE	2.66119	0.0742*	Reject
ERODE does not Granger Cause THINDIVANAM	1.95029	0.1470 NS	Accept
VELLORE does not Granger Cause ERODE	4.19715	0.0174**	Reject
ERODE does not Granger Cause VELLORE	653188	0.0021***	Reject
VELLORE does not Granger Cause THINDIVANAM	7.84274	0.0006***	Reject
THINDIVANAM does not Granger Cause VELLORE	4.44510	0.0139**	Reject
Groundnut Inter-state			
ADONI does not Granger Cause THINDIVANAM	8.49023	0.0004***	Reject
THINDIVANAM does not Granger Cause ADONI	1.35353	0.2625 NS	Accept
GONDAL does not Granger Cause THINDIVANAM	1.58558	0.2094 NS	Accept
THINDIVANAM does not Granger Cause GONDAL	1.89924	0.1544 NS	Accept
GONDAL does not Granger Cause ADONI	0.72044	0.4888 NS	Accept
ADONI does not Granger Cause GONDAL	2.49902	0.0867*	Reject

*(*** Significant at 1 percent level; ** Significant at 5 percent level; * Significant at 10 percent level; NS – Not significant)*

Table 3. Results of granger causality test for sesame

Null Hypothesis	F- statistics	Prob.	Reject H0
SESAME INTRA STATE			
ERODE does not Granger Cause CUDDALORE	1.91031	0.1528NS	Accept
CUDDALORE does not Granger Cause ERODE	4.36727	0.0149**	Reject
SALEM does not Granger Cause CUDDALORE	1.28630	0.2803 NS	Accept
CUDDALORE does not Granger Cause SALEM	5.83929	0.0039***	Reject
VILLUPURAM does not Granger Cause CUDDALORE	4.85845	0.0095***	Reject
CUDDALORE does not Granger Cause VILLUPURAM	7.68602	0.0007***	Reject
SALEM does not Granger Cause ERODE	0.83254	0.4376 NS	Accept
ERODE does not Granger Cause SALEM	6.97344	0.0014***	Reject
VILLUPURAM does not Granger Cause ERODE	3.75925	0.0263**	Reject
ERODE does not Granger Cause VILLUPURAM	7.04133	0.0013***	Reject
VILLUPURAM does not Granger Cause SALEM	7.68939	0.0007***	Reject
SALEM does not Granger Cause VILLUPURAM	1.22782	0.2968 NS	Accept
SESAME INTER STATE			
AMRELI does not Granger Cause VILLUPURAM	2.36342	0.0751 NS	Accept
VILLUPURAM does not Granger Cause AMRELI	1.95987	0.1242 NS	Accept
KULBARNI does not Granger Cause VILLUPURAM	2.72645	0.0476**	Reject
VILLUPURAM does not Granger Cause KULBARNI	1.7919	0.1529 NS	Accept
KULBARNI does not Granger Cause AMRELI	1.75337	0.1604 NS	Accept
AMRELI does not Granger Cause KULBARNI	3.89406	0.0109**	Reject

*(*** Significant at 1 percent level; ** Significant at 5 percent level; NS – Not significant)*

Granger-causes Salem (p = 0.0014). Additionally, there is bidirectional causality between Erode and Villupuram, with both directions showing significant p-values (p = 0.0013 and p = 0.0263). However, no causality was detected between certain market pairs, such as between Erode and Cuddalore (p = 0.1528), and between Salem and Villupuram in one direction (p = 0.2968).

In the interstate markets, the relationship between Villupuram and Kulbarni shows unidirectional causality, with Kulbarni Granger-causing Villupuram (p = 0.0476), but the reverse is not true (p = 0.1529). Additionally, Amreli Granger-causes Kulbarni (p = 0.0109), while no causality was detected between Amreli and Villupuram in either direction (p = 0.0751 and p = 0.1242). These findings highlight important interdependencies and directional price influences within both intrastate and interstate Sesame markets.

4. CONCLUSION

This study analysed the market integration of selected oilseed crops in intrastate (Sesame-Sivagiri, Thindivanam, Viruthachalam, Attur) and

Groundnut- Thindivanam, Punjaipuliyampatti, Sevur, Vellore) and interstate (Sesame-Tamil Nadu, Karnataka, Gujarat and Groundnut-Tamil Nadu, Gujarat, AP) Johansen cointegration were used. The data on prices were found to non-stationary are converted to stationary using differencing and the lag length is determined using AIC, SBC criterion.

The Granger Causality for Sesame there is bidirectional causality between Sivagiri and Thindivanam; Viruthachalam and Thidivanam, unidirectional causality between Viruthachalam to Attur, Viruthachalam to Sivagiri, Thidivanam to Attur. Groundnut showed bidirectional causality between Vellore and Thindivanam, Punjaipuliyampatti and Vellore, whereas unidirectional causality between Thindivanam to Punjaipuliyampatti, Sevur to Punjaipuliyampatti. In case of sesame there is a Unidirectional causality between Karnataka to Tamil Nadu, Gujarat to Karnataka, Gujarat to Tamil Nadu. Groundnut showed bidirectional causality between Tamil Nadu and Gujarat and unidirectional causality between Andra Pradesh to Tamil Nadu, Andra Pradesh to Gujarat. The magnitude of increase in oilseeds production calls for the systematic research in this area. Technical breakthrough, crop management and uncertainty in the returns to investment ensuring from the cultivation in rainfed areas are the factors that obstructs the production process. A meticulous study on constraints that obstruct the production process can help in understanding the problems and bringing the new technology. There is a need to address new challenges that transcend the traditional decision-making horizons of producers, consumers and policymakers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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