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Threshold Cointegration and Price Transmission in Commodity Marketsof India

A. Mishra, R.P. Kumar
National Institute of Food Technology Entrepreneurship and Management, Sonipat (Delhi NCR), India

ABSTRACT

The **purpose** of this research work is to examine the relationships and price dynamics between agricultural commodities in India, i.e.maize, wheat, barley and soybean. Our approach is to study the long-term relationship using the **method** of modelling the price transmission for both linear and threshold autoregressive (AR) models and vector error correction (VEC) models. **Results** revealed that all the price series are well integrated, and threshold error correction models prove that all price series move to restore the long-run relationship, whereas commodity stock prices respond slightly faster than market prices in the short-run. **Conclusions** from this study show that understanding the price transmission flow and its impact on pricing might help in making better trading strategies. It also regulates the public policy implications of the active participation of farmers in national-level commodity exchanges.

Keywords: price transmission; market integration; threshold cointegration; pricing

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Пороговая коинтеграция и ценовая трансмиссия на сырьевых рынках Индии

А. Мишра, Р.П. Кумар
Национальный институт предпринимательства и менеджмента пищевых технологий, Сонипат (Дели NCR), Индия

АННОТАЦИЯ

Целью данной исследовательской работы является определение взаимосвязей и динамики цен между сельскохозяйственными товарами в Индии: кукурузой, пшеницей, ячменем и соей. Наш подход заключается в изучении долгосрочных отношений с помощью метода моделирования ценовой трансмиссии как для линейных и пороговых моделей авторегрессии (AR), так и для векторных моделей коррекции ошибок (VEC). Результаты показали, что все ценовые ряды являются интегрироваными, а пороговые модели коррекции ошибок доказывают, что они движутся к восстановлению долгосрочной взаимосвязи, в то же время цены на сырьевые акции реагируют немного быстрее, чем рыночные цены в краткосрочной перспективе. **Выводы** из данного исследования показывают, что понимание потока ценовой трансмиссии и его влияние на ценообразование может помочь в разработке наилучших торговых стратегий. Кроме того, происходит регулирование последствий государственной политики при активном участии фермеров в товарообороте на национальном уровне.

Ключевые слова: ценовая трансмиссия; рыночная интеграция; пороговая коинтеграция; ценообразование

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INTRODUCTION

Agricultural trade has been one of the most important aspects of the economies of developing countries for years. It is associated with exports and imports and how domestic prices are integrated with world markets. Many recent studies show that developing countries have relaxed their policies after the 2007–2008 food crisis; they can keep the markets integrated with world agri-commodity prices[1–3]. Researchers have used the Law of One Price (LOP) concept to examine the market linkages in the existence of arbitrage, transport, and other transaction costs. This article has studied the price integration of Indianagri-commodities, considering four commodities: maize, wheat, barley and soybean. It is to establish market integration models between commodity stock prices (NCDEX[1] data) and market prices (eNAM[2]/Agmarknet prices). This article contributes to and extends the limited literature specific to market integration and price transmission for agri-commodities in the Indian context. We considered fouragri-commodities: (i) maize — India is ranked 4th in maize cropland area and 7th in production among maize-producing countries. India's maize production is more than 27.8 million MT during FY 2018–2019[3]; (ii) wheat — India is the second-largest wheat producer with more than 103.6 million MT in FY 2018–2019[4]; (iii) barley — is another critical crop primarily used as feed grains and consumed commercially for animal feed, beer production, seed and human food applications; and (iv) soybean — which is the world'slargest produced seed legume and contributes more than 26% of the world's edible oil and about 65% of the global protein concentrate for farm animals' feeding. Soybean's share is more than 41% of the total seedoils and more than 25% of the edible oils [4]. The market price and commodity stock price trends are shown in the *Appendix, Fig. A1 to Fig. A4* for these four commodities.

REVIEW OF LITERATURE

Market integration has been studied using various models and statistical approaches and has a growing literature available. It gained more attention after the 2008 food crisis [1, 2, 5–9]. It occurs when prices of goods follow the same pattern in two spatially separated areas over a period of time [10]. It is believed that if markets are more integrated, they will yield lower price volatility [5]. Generally, market integration refers to the degree but not a specific relationship [9]. Market integration usually requires the existence of price transmission among the markets, which may be in the form of cointegrated prices.

As many researchers have studied market integration and price transmission, some studies confirm the existence of integration [1, 11, 12] but few, in contrast, conclude weak or partial integration (*Table 1*) [13]. Beginning with Fackler, who presented the three market integration measures with a more specific economic interpretation [14]. They have examined how spatial equilibrium behaves when an access demand shock from one market affects another. Ahmedhas proposed a new VAR-BEKK-GARCH model based on the Chinese stock market, international Oil market, and commodities study [3]. They found a one-directional relationship between stock prices and oil prices relative to commodity prices. They also established a shock spillover between oil and stock prices. Arnade has used an ECM model to study long- and short-run price transmission [8]. They also examine the impact of Chinese commodity markets on world commodity prices. They concluded that short-run price transmission is lower than long-run transmission, and the impact of price transmission highly depends upon the commodity. Mensi has examined the transmission between commodity prices and stock prices using a VAR-GARCH model [6]. They have concluded the existence of transmission for return and spillover. Rapsomanikis had extensively discussed market integration and price transmission among agri-commodities in several developing countries, including India [11]. They found that equilibrium exists for commodities like wheat, maize, and milk in the long run but not for meat. Also, domestic transmission among retail and wholesale prices was found to besignificant. Esposti has investigated the price transmission if the market is uncertain for Italy and world prices [15]. They have used the VECM framework and found that the impact of a price bubble is minimal on the price spread and can be controlled by trade policies. Rezitis has used a non-linear ARDL model to investigate vertical price transmission for the Finland dairy market [16]. The researcher established thata positive — long-run price asymmetry is present. Martin-Moreno has used TAR-ECM and Markov-switching approaches to study European oil prices and found short-term and long-term equilibrium [17]. Bonatoinvestigates price correlations and spillovers with the GARCH model for commodities and oil [1]. Svanidze examined the market integration for wheat among several markets using linear and threshold error correction models, which suggest that trade and transaction costs broadly impact the prices [12]. Boffa studied the market integration among wholesale and domestic markets and examined the vertical integration from wholesale to retail prices [13]. Interestingly, they found a perfect vertical integration for wheat only but not forother commodities. They also studied the impact of GST and additional costs on market integration.

Qinexamined the oil, commodity and financial prices using a threshold error-correction model for the US markets [18]. The researchers have found a short-term non-linear asymmetric price transmission pattern, whereas long-term equilibrium does not show asymmetry. Gannevalused Threshold Vector Error Correction Models

[1] NCDEX — National Commodity & Derivatives Exchange Limited is an Indian online commodity and derivative exchange based in India. URL: https://www.ncdex.com/ (accessed on 21.05.2022).

[2] Department of Agriculture G of I. e-NAM Overview. URL: https://www.enam.gov.in/web/ (2022) (accessed on 21.05.2022).

[3] ICAR. India Maize Scenario. URL: https://iimr.icar.gov.in/india-maze-scenario/ (2020) (accessed on 02.11.2021).

[4] IBEF. Wheat production may cross 113 million tonnes: Skymet. URL: https://www.ibef.org/news/wheat-production-may-cross-113-million-tonnes-skymet (accessed on 02.11.2021).

(TVECM) to study market cointegration and price volatility [10]. Garcia-Germán also used error correction models (ECM) to study the impact of international prices on the agri-commodities of European markets and observed a long-run relationship but lower price transmission elasticity [19]. Ceballosextensive work examined the price transmission and volatility of agri-commodities for 41 food products in 27 countries [5]. Primarily observed a lead-lag relationship among the market prices and price volatility for maize, rice and wheat. Abdulaialso observed a long-run price equilibrium among the significant maize markets in Ghana and concluded that markets are well integrated [20]. Elleby used the two-fold regression method based on estimated price transmission elasticities and domestic food price changes [2]. They concluded that middle-income countries broadly impact international food prices. Greb'sextensive work and conclusions are based on the VECM model using log and short-term price transmission coefficients [7]. Drabikhas studied the US maize price integration with emery market prices and observed an imperfect price transmission [21]. Lence used Brand — TVECM to conclude that transfer cost is underestimated and speed of price transmission is also biased [22]. Hatzenbuehler has studied the prices of seven agri-commodities in Nigerian food markets concerning world and neighboring countries [23]. The price transmission was observed to be high for rice and coarse grains. Hassounehexamined the wheat prices using threshold vector error correction and multivariate generalized autoregressive conditional heteroscedasticity models and found that price adjustments are in sync with retailers' marketing margins [24]. Also, there is a long-run equilibrium for Slovenian wheat market prices. Distefano examined the rise of arbitrariness in the price formation mechanism [25].

RESEARCH GAP

Market integration is a well-discussed topic and has a growing literature but most of the work has been done either considering spot — future prices or domestic — international prices. Here, we have observed a gap in which market integration and price transmission are not explored mainly from the same commodity-multiple market perspective. We have taken this opportunity to study the integration of prices among multiple commodities and multiple markets.Our study has incorporated two major markets — commodity (stock) market prices and market prices (eNAM) for fourcommodities — maize, wheat, barley, and soybean. Our approach is more holistic and has included all established models of access price transmission. We tried to find out the answers to the questions below:

1. Do market integration and price transmission exist between India's domestic agri-commodity markets?
2. If price transmission exists, then what are the transmission mechanisms?

Threshold cointegration is employed to answer two research questions: are the pairs of price series tied together by a long-run relationship, and which of the series moves to restore the long-run relationship? The findings of this study can be used to understand the price transmissionflow and its impact on pricing to make relative trading strategies; if a commodity is being traded-in multiple markets. The farmers are trading directly at eNAM, and how far they get fair prices in the context of other markets'pricesis a great concern for policy implications.[5] It also regulates the public policy implications oftheactive participation of farmers in national-level commodity exchanges.

METHODOLOGY

In general, there are three types of price transmission; (i) spatial transmission: prices cointegrated between two spatially separated markets for the same commodity; (ii) vertical transmission: cointegrated prices between two points or stages of the value chain e.g.— the price of wheat and price of floor and (iii) cross-commodity: cointegrated prices between two commodities; primarily, they may have substitution effects. Fackler has defined market integration as a measure of the degree to which demand and supply shocks ascending in one market are transmitted to another market [9]. Market integrationis mainly measured by the "price ratio" (R_{XY}) associated with a market shock.

$$R_{XY} = \frac{\partial P_Y / \partial \varepsilon_X}{\partial P_X / \partial \varepsilon_X}, \quad (1)$$

where P_X and P_Y refer to the prices in the markets X and Y respectively, ε_X represents a hypothetical shock in market X and ∂ is for the first-order derivative of the respective price to the market shock. Rapsomanikishas suggested three components to understand the price transmission (i) Co-movement and completeness of adjustments (ii) dynamics and speed of adjustments and (iii) asymmetry of response may be upward or downward [11]. The first completeness of price transmission is in sync with the Law of One Price (LoP). In contrast, the second primarily depends upon policies and market power (short-run impact), several marketing

[5] Department of Agriculture G of I. e-NAM Overview. URL: https://www.enam.gov.in/web/ (2022) (accessed on 21.05.2022).

Table 1

Summaries of the Studies on Price Transmission

Study Reference	Methods	Period	Commodity type	Summary
Spillover network of commodity uncertainties [26]	VAR, DY 2014	2007–2016	Energy, precious and industrial metals, and agricultural	Connectedness tends to increase during the period of crisis and the global economic situation influences the connectedness of commodity uncertainty indexes
Vertical price transmission in wheat and flour markets in Bangladesh [27]	Threshold cointegration	2008–2016	Wheat, flour	Evidence of threshold effects hasa significant impact on the speed of adjustment toward the long-run & short-run
Spatial Price Dynamics and Asymmetric Price Transmission [28]	Threshold cointegration	2010–2016	Skim milk powder	New Zealand's export prices arethe market leader as compared with China, and Ireland's export prices are well more aligned with those in international markets
Impacts of COVID-19 and price transmission in US meat markets [29]	Threshold cointegration	2010–2020	Meat	All meat markets are well integrated and unexpected & large price movements are visible during Covid-19
Investigating the Impact of Trade Disruptions on Price Transmission [30]	Threshold cointegration	2014–2019	Commodity markets	Trade disruptions between Canada and China impacted global price transmission and resulted in market fragmentation
Asymmetric price transmission in a changing food supply chain [31]	ECM, threshold cointegration	2008–2018	Salmon	Price transmission relationship exists between the markets for fresh salmon; but not for smoked salmon
Food security and the functioning of wheat markets in Eurasia [12]	TECM	2006–2009	Wheat	A stronginfluence oftrade costs on market integration in Central Asia
Threshold cointegration and spatial price transmission when expectations matter [22]	TVECM, threshold cointegration	2018	Agri commodity	Transfer costs are systematically underestimated and the speed of price transmission is biased in three regime models
Global relationships across crude oil benchmarks [32]	Threshold cointegration	2002–2014	Crude oil	All price series move to restore the long-run relationship is at least one regime
How integrated is the Indian wheat market? [33]	Momentum-threshold autoregressive (M-TAR) model	1984–2003	Agri commodity	Asymmetric adjustments of wheat prices indicate that price signals within states are transmitted in an asymmetric manner
Cointegration and threshold adjustment [34]	Threshold cointegration	1964–1998	Interest rates	Equilibrium exists between short and long-term interest rates but the adjustments from disequilibrium are asymmetric
Spatial price transmission and asymmetry in the Ghanaian maize market [20]	TVECM, threshold cointegration	1980–1997	Maize (Agri commodity)	All major maize markets in Ghana are well integrated

Source: Compiled by the authors.

Notes: VAR: vector autoregressive; DY 2014: Diebold and Yılmaz (2014) model; ECM: Error Correction Model; TECM: Threshold Error Correction Model; TVECM: Threshold Vector Error Correction model; M-TAR: Momentum Threshold autoregressive.

stages, contracts between agents, and transfer costs. As per [11], if P_{1t} and P_{2t} are the prices in spatially separated markets that are integrated in the same order and have stochastic trends, then

$$P_{1t} - \beta P_{2t} = \mu_t . \qquad (2)$$

The above equation is called cointegration regression, where ˌ is a cointegration vector, and M is stationary. In other words, the long-run relationship is also termed the cointegrating regression.

As a first step, we have to consider the time-series properties of price data. For that, we have used stationarity and cointegration methods. As per the literature, most of the articles started with an assessment of stationarity in individual price series. We have used the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to check the stationarity of data, and both tests have been conducted with two models: (a) with intercept and (b) with intercept and trend. Both the tests have been executed at the level, and the first difference and Akaike information criterion (AIC) have been used for optimal lag selection. If the series is not integrated in the same order, then, by definition, they are not cointegrated. After that, we employed thecointegration tests. Engle and Granger (1987) introduced the concept of cointegration, which occurswhen two or more variables are nonstationary but their linear relationship is stationary. Cointegration infers that the price variables move together in the long run but may diverge in the short-run [29]. We can present the standard cointegration relationship as equation (3) below; which shows two nonstationary variables that are linked by a long-run, stable relationship

$$y_t = \alpha + \beta x_t + v_t , \qquad (3)$$

where y_t and x_t represents prices at different levels at the time t and error correction term as $v_t = \varphi v_{t-1}$. The behaviour of v_t decides whether the variables are cointegrated. Following the Engle and Granger (1987) cointegration testing procedure we have tested residuals for stationarity (*Appendix, Table A1*). We also used the Johansen cointegration test to check the cointegration between two or more time series. It has the advantage over the Engle-Granger and the Phillips-Ouliaris methods, which can estimate more than one cointegration relationship, if the data set containstwo or more time series. If there is a time series with order p, then

$$Y_t = \prod\nolimits_1 Y_{t-1} + \prod\nolimits_2 Y_{t-2} + \ldots + \prod\nolimits_p Y_{t-p} + u_t , \qquad (4)$$

where Y_t is an $n \times 1$ vector of time series that are integrated of order one, that is, I(1), u_t is an $n \times 1$ series of innovations while $\prod_1$ to $\prod_p$ are $m \times m$ coefficient matrices, which is called the impact matrix and determines the extent to which the system is cointegrated.

Two likelihood ratio tests are used to determine the number of cointegrating vectors — (i) Trace test and (ii) Maximum Eigenvalue.

Once stationarity and cointegration tests are complete with confirmation of cointegration, we estimate whether the price transmission and correction of short-run disequilibria are characterized by non-linear, asymmetric behaviour. To test the non-linearity, we can apply the residuals of equation 3 to test whether the threshold cointegration exits. If the tests fail to reject linearity, we can model the residuals using an autoregressive (AR) method and model the cointegrated system as a VEC model. In the third step, we implement three tests to check the linear behaviour (linearity). These are (i) Terasvirta test — which relies on Taylor series expansion of the neural network. (ii) White test — which is also based on the theory of neural networks. (iii) Tsay test — which is Turkey'snon-additivity type test.

Non-linear behaviour in error correction terms suggests that they do not follow a linear Autoregressive process. In particular cases, it can be more appropriately characterized by a self-exciting threshold auto-regression (SETAR) model [29]. The SETAR approach allows for asymmetric adjustment to shocks with the error correction term now following

$$v_t = \begin{cases} \varphi_L v_{t-1} + \varepsilon_t \; : v_{t-1} < T \\ \varphi_H v_{t-1} + \varepsilon_t \; : v_{t-1} \geq T \end{cases} , \qquad (5)$$

where Threshold value of the two-regime case with regimes L and H. Asymmetric adjustment occurs when φ_L is not equal to φ_H. If the VEC model can be given by

$$\begin{bmatrix} \Delta y_t \\ \Delta x_t \end{bmatrix} = \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} v_{t-1} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} \Delta y_{t-1} \\ \Delta x_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^x \end{bmatrix} . \qquad (6)$$

This representation can also be extended to the threshold vector error correction model (TVECM) such as

$$\begin{bmatrix} \Delta y_t \\ \Delta x_t \end{bmatrix} = \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix} + \begin{bmatrix} \alpha_1^L \\ \alpha_2^L \end{bmatrix} v_{t-1}^L + \begin{bmatrix} \alpha_1^H \\ \alpha_2^H \end{bmatrix} v_{t-1}^H + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} \Delta y_{t-1} \\ \Delta x_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^x \end{bmatrix} , \qquad (7)$$

where L and H are two regimes and v^L and v^H denote the error correction terms for both regimes respectively. Threshold behaviour in cointegration can thus be described by either a SETAR model of the residuals from the cointegrating regression or a TVECM (*Appendix, Table A2*). There could be four possible scenarios; (i) Cointegration and threshold effects — threshold cointegration case, (ii) Cointegration and no threshold effects — linear cointegration case, (iii) No cointegration and no threshold effects — no cointegration case, and (iv) Threshold effects and no cointegration.

We have used both AR and SETAR models and VEC and TVEC models to understand the dynamics of price adjustment. We applied standard and generalized impulse response functions to examine pricebehaviour. Impulse responses depend on the timing, size, and direction of the shocks [29]. The generalized impulse is given by

$$GIF\left(y_{t+1}\right)=E\left(y_{t+k}\mid y_t+v,\ldots,y_{t-j}\right)-E\left(y_{t+k}\mid y_t,\ldots,y_{t-j}\right). \quad (8)$$

We have used regime-specific impulse responses, which use parameters from each regime for the threshold models. Please referto Hansen[35] for a further methodological explanation.

DATA

We have used monthly prices for the period of 2005 to 2019, and lastly, the criteria for selecting the commodity are:

1. Commodities should be listed in more than one market. We have taken four commodities — maize, wheat, barley, and soybean- listed in both NCDEX and thepan-India electronic trading portal (eNAM) and have IMF price data.
2. Volume or quantity of trade in the last five years for that commodity.
3. A foodgrain is being selected considering its importance in the food basket.
4. We have not considered the storable or non-storable categories of commodities.
5. Also, we are not categorizing based on "seasonal" and "non-seasonal"commodities.

The first data source forthe price series is NCDEXCommodity Index data — commodity market data from NCDEXfor 2005 to 2019. We will refer to this data as "Commodity StockPrice". Thesecond price series is Agmarknetdata — wholesale market data for the pan-India electronic trading portal (eNAM)or Agmarknetand we will refer to this data as "Market Price".

RESULTS AND DISCUSSION

Before westart establishing the model for fourcommodities — maize, wheat, barley, and soybean, we have observed that, in general, market prices are higher than commodity stock prices; however, there are cases where this relationship is inverted. Such cases are approximately 12.6% for barley, 32.3% for maize & wheat, and only 8% for soybean.

As the first step, we tested all the time series for stationarity using the Augmented Dickey-Fuller (ADF) Unit root (stationary) test. Along with the Phillips Perron test to check the unit root, the results are listed in *Table A3* of the Appendix. Results show that price series are not stationary at level but become stationary if we take the first difference. All econometric tests and estimations are conducted using the log prices of the commodities.

Once the stationarity is confirmed, we execute the Johansen cointegration testto understand the long-term association between the markets by examining the co-movement of price signals. The null hypothesis is that there areno cointegrating equations ($r = 0$) and at most one cointegrating equation ($r < 1$). Referring to *Table 2* the null hypothesis of no cointegration was rejected at a 5% significance level that shows the existence of cointegration between market prices and commodity stock prices. Additionally, we also used the Phillips-Ouliaris Cointegration Test and the results are presented in *Table A4* in the appendix. Both tests confirm that all the price series are cointegrated and hence VEC models are appropriate for modelling these price series.

Once the cointegration behaviour is confirmed for all the price series, we need to test the non-linear behaviour in the error correction term. Tests of the residuals from the cointegrating regressions are presented in *Table A5* of the Appendix. The results confirm that linearity can't be rejected at 5% significance level for soybean and wheat. At the same time, the barley and maize series are found non-linear by all three tests. Non-linearity conditions have implications for the models considered below, namely differences in transmission and adjustment across the different regimes indicated by thresholds [29]. Next, it's necessary to test for the number of thresholds for barley and maize price series. *Table A6* of the Appendix shows the results of SETAR model of the cointegration equation residuals. In the SETAR model, we have three null hypotheses: (i) no threshold vs. one threshold, (ii) no threshold vs. two thresholds, and (iii) one threshold vs. two thresholds. The results suggest one threshold for both barley and maize. Based on the linearity, we have anAR model for soybeans and wheat and the SETAR model for barley and maize. The estimated parameters are given in *Table 3*. We are interested in the autoregressive parameters, as the larger the autoregressive parameters, the slower will be the adjustment to shocks in the price equilibrium. All the autoregressive parameters are statistically significant, which means the time-related and sequential relationships among the prices. For barley and maize, the regimes are distinguished by the speed of adjustment over the two periods. For barley, the AR(1) term is very close to the high regime in the low regime and almost similar for AR(2).

Table 2

Johansen's Cointegration Test Results

	Number of Cointegrating Vectors			
	None		At most one	
	Max. Eigenvalue	Trace	Max. Eigenvalue	Trace
Barley	22.342*	23.338*	0.996	0.996
Maize	32.800*	36.151*	3.351	3.351
Soybean	65.275*	66.436*	1.161	1.161
Wheat	51.829*	53.612*	1.783	1.783

Source: Author's analysis.

Note: Trace test indicates 1 cointegratingeqn(s) at the 0.05 level.Max-eigenvalue test indicates 1 cointegratingeqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Table 3

AR and SETAR Estimates

		Intercept		AR1		AR2	
		Estimate	Std Error	Estimate	Std Error	Estimate	Std Error
Barley MP – CSP	Low regime	–0.004	0.001	0.552	0.019	0.363	0.020
	High regime	0.002	0.001	0.578	0.027	0.368	0.029
Maize MP – CSP	Low regime	0.001	0.001	0.527	0.018	0.401	0.019
	High regime	0.015	0.004	0.699	0.033	–0.017	0.051
Soybean	MP – CSP	0.007	0.000	0.640	0.018	0.295	0.018
Wheat	MP – CSP	0.004	0.000	0.627	0.017	0.354	0.018

Source: Author's analysis.

Note: MP: market price, CSP: commodity stock price.

This means the speed of adjustment is the same for both regimes. Likewise, if we consider maize, the high regime parameter is higher than the low regime, but it is reversed in AR(2), which concludes the quicker adjustments in the low regime. Referring to *Table A6* — of the Appendix, the coefficient of error correction term is larger and more significant for the market prices.

Orthogonalized impulse response functions are shown in *Fig.* Shocks to commodity stock prices are quick for barley, maize and soybean in the short-run. For wheat commodity stock prices, shocks are not visible until the first two periods but, after that, move to negative and show an asymmetric relationship in the long run. Barley and wheat market prices, trigger movements in the short-run and responses to shocks are mostly faster than responses in maize and soybean. The impulses indicate that both market and commodity stock prices respond in the short-run andlong-run, whereas commodity stock prices respond slightly faster than market prices. To conclude, impulse responses indicate all the price series are well-integrated. The findings can be helpful for investors as well as policymakers. Since both markets are integrated, the shocks can be more prolonged during the crisis, which can be considered while preparing the policies.

CONCLUSION

We investigated the price dynamics of agri-commodity prices between stock and market prices for India. We have considered four agricultural commodities — maize, wheat, barley and soybean. We used linear and threshold autoregressive (AR) models and vector error correction (VEC) modelsfor long- and short-term relationships. Prima-facie, all four commodity stock prices are

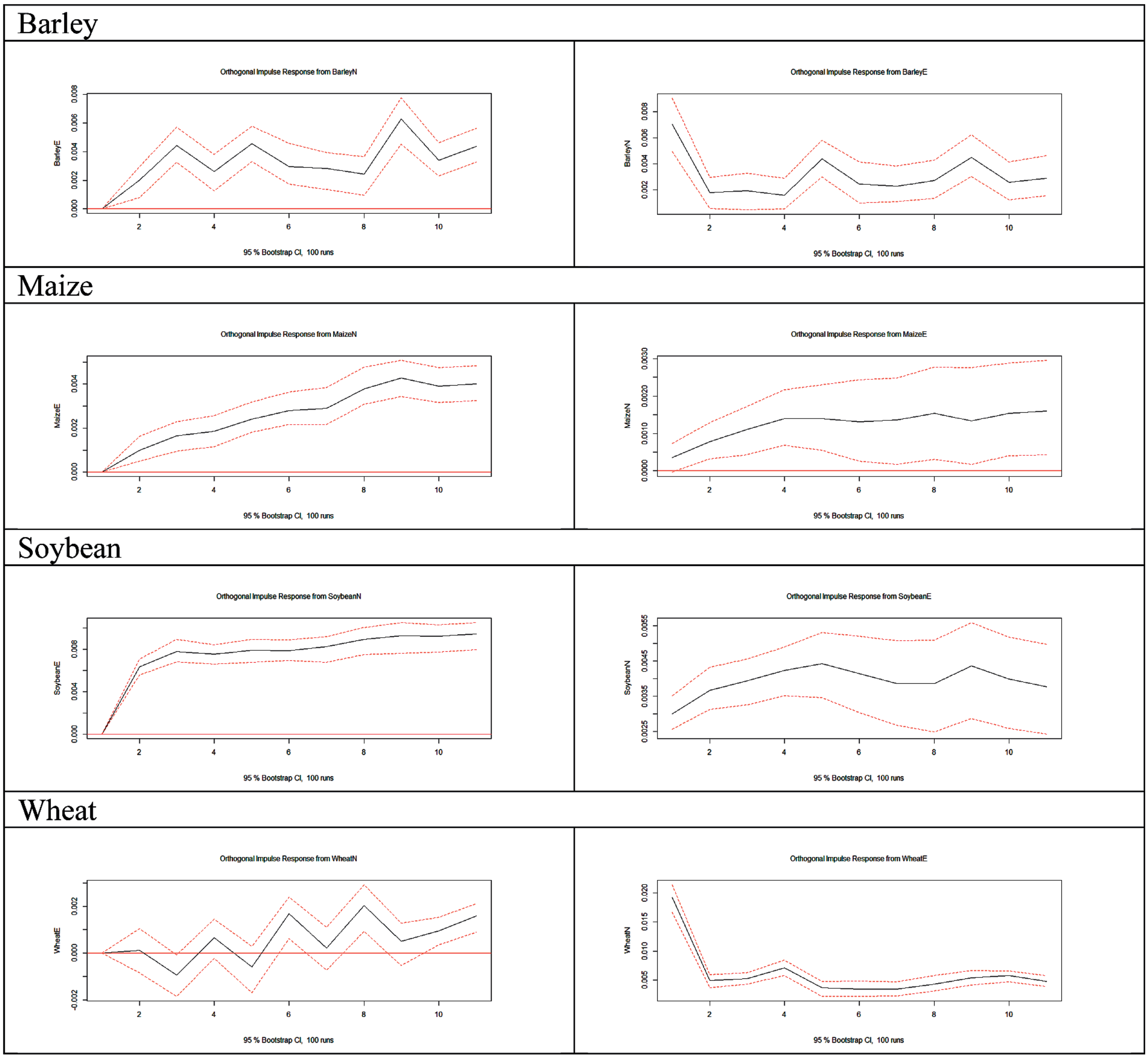

Fig. **Impulse Response**

Source: Author's analysis.

Note: Commodity name with suffix "E": market price andsuffix"N": commodity stock price.

cointegrated with market prices. Results reveal that all the price series are well integrated, and threshold error correction models prove that all price series move to restore the short- and long-run relationship, whereas commodity stock prices respond slightly faster than market prices in the short-run. The findings of this study can be used to understand the price transmission flow and its impact on pricing to make relative trading strategies if a commodity is being traded-in multiple markets. The farmers are trading directly at eNAM and how far they get fair prices in the context of other markets' prices is a great concern for policy implications. It also regulates the public policy implications of the active participation of farmers in national-level commodity exchanges.

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ABOUT THE AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

Arunendra Mishra — Research Scholar, Department of Food Business Management and Entrepreneurship, National Institute of Food Technology Entrepreneurship and Management, Sonipat (Delhi NCR), India
Арунендра Мишра — научный сотрудник, департамент пищевой промышленности и предпринимательства, Национальный институт предпринимательства и управления пищевыми технологиями, Сонипат (Дели NCR), Индия
https://orcid.org/0000-0002-6070-1373
Corresponding author / Автор для корреспонденции:
arunendra.niftem@gmail.com

Prasanth R. Kumar — PhD in Strategic Finance, Assist. Prof., Department of Food Business Management and Entrepreneurship, National Institute of Food Technology Entrepreneurship and Management, Sonipat (DelhiNCR), India
Прасантх Р. Кумар — PhD в области стратегических финансов, доцент, департамент пищевой промышленности и предпринимательства, Национальный институт предпринимательства и управления пищевыми технологиями, Сонипат (Дели NCR), Индия
https://orcid.org/0000-0001-5299-7701
prasanth@niftem.ac.in

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APPENDIX

Table A1

Granger Causality Tests Statistics for Selected Agricultural Commodities

	Null Hypothesis	F-Statistic	Prob.	Direction	Relationship
Barley	CSP does not Granger Cause MP	17.2323	7.00E-17	Bi-directional	MP ↔ CSP
	MP does not Granger Cause CSP	16.5151	4.00E-16	Bi-directional	
Maize	CSP does not Granger Cause MP	16.9235	1.00E-16	Bi-directional	MP ↔ CSP
	MP does not Granger Cause CSP	2.52123	0.0276	Bi-directional	
Soybean	CSP does not Granger Cause MP	102.032	9E-101	Bi-directional	MP ↔ CSP
	MP does not Granger Cause CSP	5.46742	5.00E-05	Bi-directional	
Wheat	CSP does not Granger Cause MP	9.83574	2.00E-09	Bi-directional	MP ↔ CSP
	MP does not Granger Cause CSP	10.0031	2.00E-09	Bi-directional	

Source: Author's analysis.
Note: MP: market price, CSP: commodity stock price.

Table A2

VECM Model

VECM Model	ECT	Intercept	Cointegrating vector
Barley: MP	−0.0272(0.0060)***	−0.0432(0.0097)***	1
Barley: CSP	0.0026(0.0036)	0.0046(0.0058)	−1.209868
Maize: MP	−0.0198(0.0036)***	−0.0089(0.0018)***	1
Maize: CSP	0.0040(0.0021).	0.0022(0.0010)*	−1.061873
Soybean: MP	−0.0602(0.0073)***	−0.0045(0.0007)***	1
Soybean: CSP	−0.0139(0.0043)**	−0.0008(0.0004)*	−1.001355
Wheat: MP	−0.0640(0.0099)***	0.0165(0.0025)***	1
Wheat: CSP	−0.0216(0.0105)*	0.0063(0.0026)*	−0.9640472

Source: Author's analysis.
Note: MP: market price, CSP: commodity stock price. ***, ** and * indicate the significance of t-statistics at 1%, 5% and 10% level of significance, respectively.

Table A3

Unit-Root Test Results

	ADF (first difference)		PP (first difference)	
Commodity	Intercept	Intercept & trend	Intercept	Intercept & trend
Barley MP	−2.060	−3.700**	−2.790	−14.283***
Barley CSP	−1.902	−4.267***	−1.783	−5.843***
Maize MP	−1.642	−44.215***	−2.124	−4.179***
Maize CSP	−1.466	−54.039***	−2.004	−54.962***
Soybean MP	−1.786	−44.262***	−2.094	−81.267***
Soybean CSP	−2.768	−55.693***	−1.991	−56.037***
Wheat MP	−0.997	−29.792***	−2.354	−39.818***
Wheat CSP	−0.668	−15.768***	−2.293	−19.674***
Critical values				
1% level	−3.960635			
5% level	−3.411076			
10% level	−3.127359			

Source: Author's analysis.

Note: MP: market price, CSP: commodity stock price. The table contains the t-statistics of the ADF & PP tests results, where *** and ** indicate the significance of t-statistics at 1% and 5% level of significance, respectively.

Table A4

Phillips-OuliarisCointegration Test for Selected Agricultural Commodities

	demeaned	p-value
Barley	−404.7***	0.01
Maize	−119***	0.01
Soybean	−631.35***	0.01
Wheat	−1037.2***	0.01

Source: Author's analysis.

Note: MP: market price, CSP: commodity stock price. *** indicate the significance of t-statistics at 1% level of significance.

Table A5

Linearity Tests of Price Differences

	Terasvirta		White		Tsay	
	Statistic	P-Value	Statistic	P-Value	Statistic	P-Value
Barley	1001***	2.2E-16	11.722***	0.002848	3.022***	2.03E-24
Maize	693.75***	2.20E-16	27.275***	1.20E-06	9.153***	2.29E-21
Soybean	1126.4***	2.20E-16	4.2145	0.1216	8.588***	2.10E-52
Wheat	1678.7***	2.20E-16	2.8488	0.2407	6.929***	1.88E-281

Source: Author's analysis.

Note: MP: market price, CSP: commodity stock price. *** indicate the significance of t-statistics at 1% level of significanc.

Table A6

SETAR Specification Tests

	1vs2: Linear AR vs 1 threshold TAR (setar(2))		1vs3: Linear AR vs 2 threshold2 TAR (setar(3))		2vs3: 1 threshold TAR vs 2 thresholds TAR	
Series	Test	P Value	Test	P Value	Test	P Value
BarleyE – BarleyN						
Low regime	31.3	0.02	70.6	0.81	29.3	0.51
High regime	28.3	0.03	67.6	0.92	24.7	0.67
MaizeE – MaizeN						
Low regime	69.5	0.05	142.6	0.76	63.9	0.70
High regime	77.5	0.02	150.6	0.81	71.5	0.42

Source: Author's analysis.

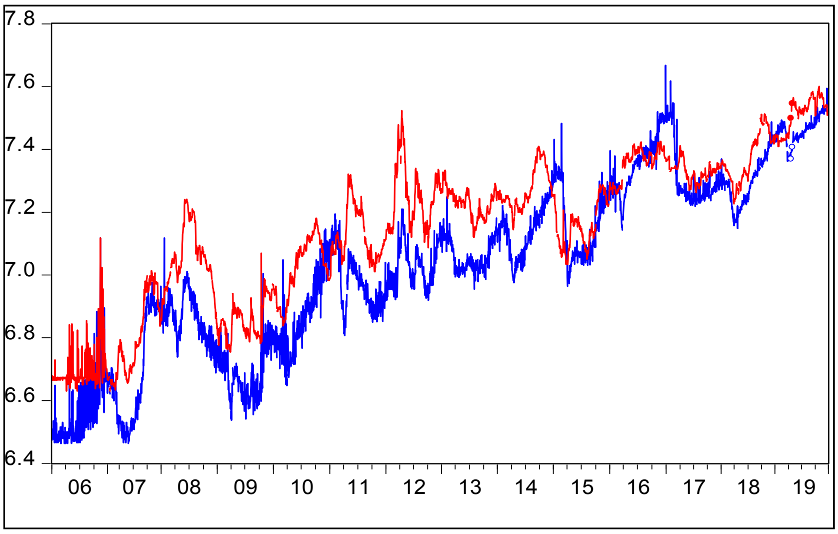

Fig. A1. **Barley Price Series**

Source: Author's analysis.

Note: Blue represent market price (MP) and red commodity stock price (CSP).

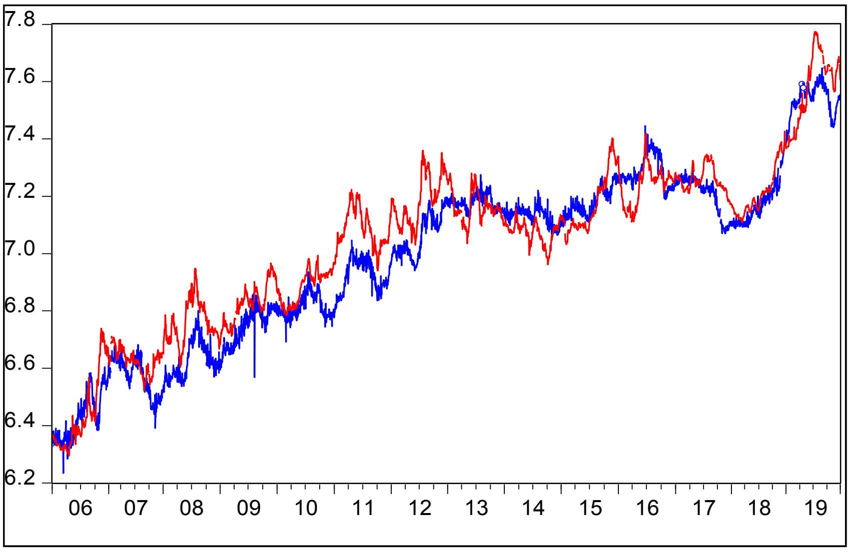

Fig. A2. **Maize Price Series**

Source: Author's analysis.

Note: Blue represent market price (MP) and red commodity stock price (CSP).

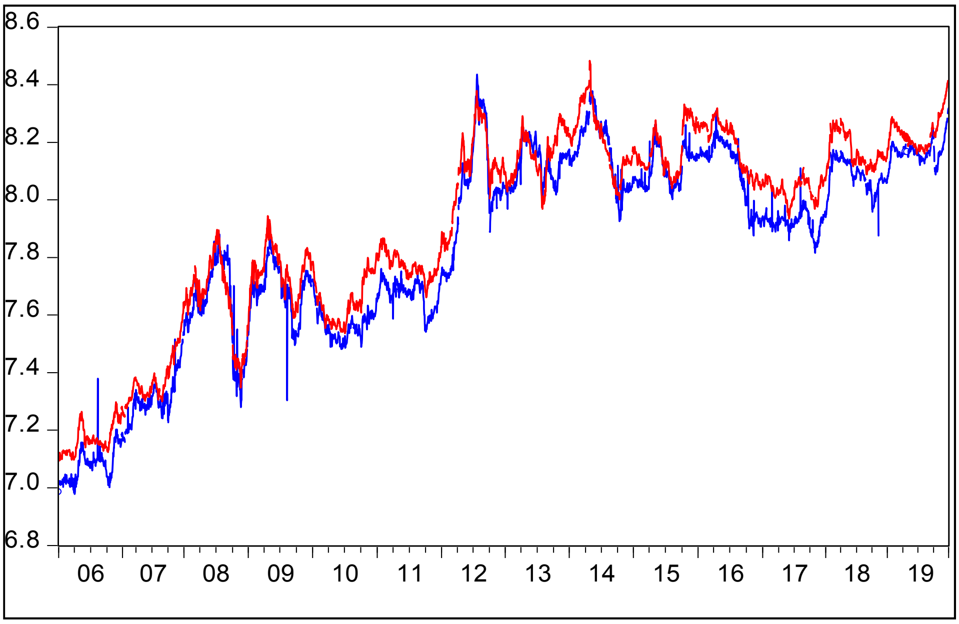

Fig. A3. **Soybean Price Series**

Source: Author's analysis.

Note: Blue represent market price (MP) and red commodity stock price (CSP).

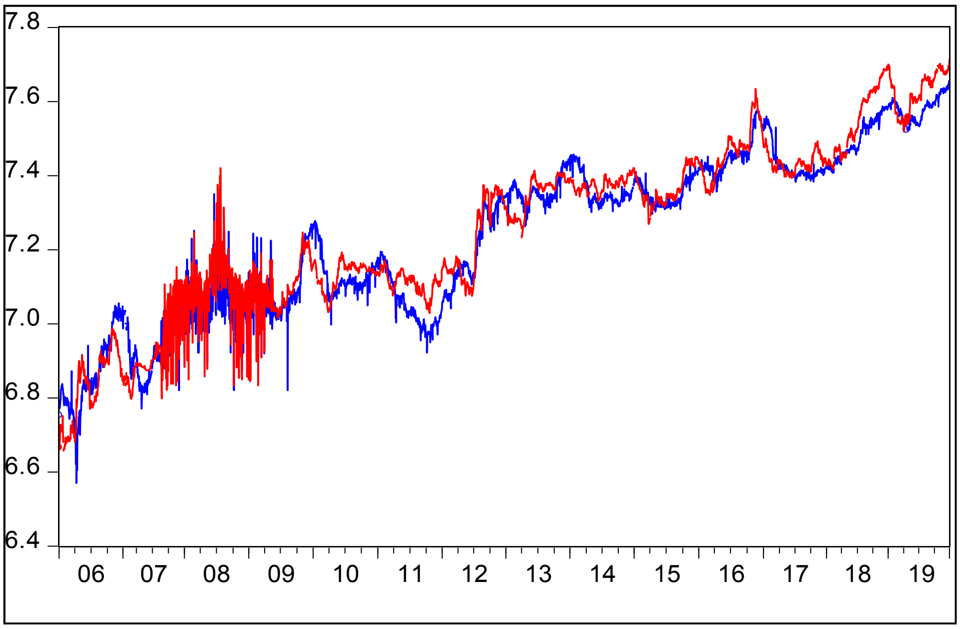

Fig. A4. **Wheat Price Series.**

Source: Author's analysis.

Note: Blue represent market price (MP) and red commodity stock price (CSP).