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Article

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Asymmetric and threshold price transmission dynamics in onion markets in India

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ABSTRACT
Functional agricultural marketing system is purported to be the silver bullet and multiplier for stimulating production and consumption and, accelerating the pace of economic and rural enterprise development. Thus, understanding effectiveness of agricultural products market price transmission dynamics in a functional agricultural marketing system is useful for all sections of societies concerned with the marketing of agricultural produce. Thus, this study was conducted to assess the market middlemen response to onion price perturbation. To stimulate policy evaluation and intervention in India onion markets, seven majors' onion markets namely: Lasalgaon (reference market), Kanpur, Mumbai, Lucknow, Korzhikode, Mysore, and Hyderabad were examined using monthly wholesale prices from January 2011 to December 2018. Market middlemen response to price shocks was examined through the framework of momentum threshold autoregressive model and a regime-switch asymmetric threshold vector error correction model. The results of the estimation procedure revealed that the markets were characterized by threshold co-integration and asymmetric response adjustment path both in the short and long run. The study results indicated that wholesalers responded faster to deviations that tend to increase their profit margin but delayed in responding to prices changes that tend to benefit the producers. We recommend stringent measures against intensification of existing regulated marketing structures that seek to favour middlemen at the expense of producers and consumers and, the conscious effort to improve market intelligence structure for efficient conduct and performance of onion markets in India.

IMPACT STATEMENT
The results of the estimation procedure revealed that the markets were characterized by threshold co-integration and asymmetric response adjustment path both in the short and long run. The study results indicated that wholesalers responded faster to deviations that tend to increase their profit margin but delayed in responding to price changes that tend to benefit the producers.

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1. Introduction

The issues of bridging discrepancies and disparity gaps in income and living standards among agricultural commodity producers amidst the multifaceted behaviour of market middlemen in the competitive market economy in developing countries to enhance rural development have attracted considerable attention over the past two decades. However, government efforts and interventions towards restructuring producers' economic standards depend magnanimously on the complexities, conduct, structure, and performance of

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agricultural markets, as well as the interlinkages that exist among producers, wholesalers, retailers, and other market agents in the economy. The dynamics of commodities prices and efficiency of prevailing marketing systems are pivotal to economic development, and are crucial for poverty alleviation and sustainable livelihood policy strategies in agrarian economies (Panagiotou, 2021). There has been a continuing debate concerning the impact and appropriateness of government roles and interventional policies in the market place and the effect of these policies on production and marketing of agricultural commodities in enhancing livelihoods. However, government intervention in setting price ceilings in a competitive market economy remain controversial. In quantitative development policy analysis, this may be justified if the intervention does not enhance price distortion and disequilibrium into the existing market structure and performance, or remedies the existing market imperfection. However, the complexities in the interlinkages that exist among intermediaries along the commodity supply value chains and the profit-maximizing seeking behaviour of markets agents or traders (middlemen) in competitive agricultural markets structure force economic actors to adjust their prices to new cost conditions in a divergent manner (Frey & Manera, 2007; Kumar et al., 2022; Lardic & Mignon, 2008; Santeramo, 2015). However, (Abdulai, 2002; Abunyuwah, 2020) noted that the effectiveness of agricultural markets in enhancing and stimulating livelihoods of agricultural commodity producers within the framework of government intervention depend extensively on the magnitude and direction of the price divergence behaviour transmitted among spatially distributed markets across major geographical boundaries of an economic space in a country.

During the past two decades, researchers have developed myriad approaches for accessing performance, integration and price transmission dynamics of agricultural markets distributed across economic space by adopting variant of econometric techniques and approaches. These statistical tools and econometric techniques that have been applied in previous literature to identify market integration and price transmission dynamics include the application of ordinary Least Squares (OLS) and correlation analysis (Cudjoe et al., 2008; Hossain & Verbeke, 2010), Ravallion dynamic model (Alderman, 1992), tests that examines the stochastic dynamic process among the spatially separated markets (linear Error Correction Model (ECM) (Barrett & Li, 2002; Engle & Yoo, 1987; Fackler & Goodwin, 2001; Goletti et al., 1995; Mcnew & Fackler, 1997).

However, contemporary market integration and price transmission dynamics analyses mostly focused on dynamic models that have the potential to capture the complex behaviour of economic agents over time (Kristoufek & Lunackova, 2015). In the context of analysing the dynamic response behaviour of agricultural market economic agents, researchers have focused on aspects concerned with the application of threshold vector error correctio model, threshold asymmetric error-correction model (Abdulai, 2002; Abunyuwah, 2020; Blake & Fomby, 1997; Enders & Siklos, 2001; Von-Cramon & Meyer, 2004, Elalaoui et al., 2018) as it's critical to understand the multifaceted behaviour of market intermediaries and, also provides the impulse to access the impact of policy intervention that concerns the direction of welfare transfer as well as the share of producers' prices paid by consumers along the supply and value chain, and the conduct of the market, and the application of Markov-switching ECM (Holmes & Otero, 2023; Rezitis & Tsionas, 2018; Surbakti et al., 2022). Moreover, the magnitude and elasticity of market integration and asymmetry provide an indication on the competitiveness and specialization of the markets according to comparative advantage (Ahmed & Singla, 2017; McLaren, 2015) and efficient utilization of production resources (Abunyuwah, 2020; Blay et al., 2015).

In India, the continuous government intervention in agricultural marketing systems to improve market efficiency, and livelihood of producers calls for critical evaluation and deeper insights into the price formation dynamics and levels of agricultural market interconnectedness and performance. In India, onion is regarded as an essential crop for commercial production and a major constituent of the cropping intensity and diversification programme for poverty alleviation as individuals' ability to purchase or not able to afford is how poverty is understood by a section of the society across the country. As a result, onions markets have become one of the most politically sensitive commodities markets, and price hikes plays significant role in in determining political fortunes and measure of good governance. Consequently, onion markets conduct has received most of the popular attention because of government interventional role in controlling price formation.

Despite the significance of the onion market conduct in policy intervention formulation in India, vast significant number of studies on spatial price transmission dynamics are modelled without considering the asymmetric behaviour of major economic actors (Ahmed & Singla, 2017; Reddy et al., 2012; Sendhil et al., 2014; Ujjwal et al., 2017; Von-Cramon, 1998) by adopting models that assume symmetric adjustment towards long-run equilibrium due to price changes. Thus, results from such studies may yield misleading estimates that may be either underestimation or overestimation of dynamic processes with regards to the behaviour of market agents. In this regard, an attempt has been made to apply a novel non-linear threshold asymmetric adjustment model that incorporates asymmetric and symmetric distributed lag effect to examine price dynamics in major onion markets in India. Thus, we contribute to previous studies that emphasize on price transmission dynamics in the Indian onion markets to provide in-depth insight into the behaviour of market agents along the onion marketing chain due to the significant of the market to government in policy formulation. The remaining sections of this paper are organized as follows. Section 2 provides a brief description of the data and econometric modeling approach adopted, and Section 3 describes the empirical analysis and results. Section 4 contains concluding remarks.

2. Data and econometrics model

To assess price transmission dynamics and market efficiency in onion markets, seven major Indian onion markets, namely Lasalgaon, Kanpur, Mumbai, Lucknow, Korzhikode, Mysore, and Hyderabad, were considered. These markets serve as the largest markets in the major onion producing states in India with Lasalgaon being the highly concentrated onion market as the reference market. The data set used for the analysis was monthly wholesale prices from January 2011 to December 2018 obtained from Agmarknet. The time span up to 2018 was chosen to delineate the effect of the covid-19 period as a result of significant artificial upsurge in commodity price during the period so as to provide a proper understanding of price dynamics and behaviour of middlemen in the conduct of the onion market in India. The univariate data generating process (DGP) of the price series was evaluated through the framework of the augmented Dickey- Fuller (ADF) test. The estimations of the subsequent econometric models were based on the logarithm transformation of the dataset.

2.1. Threshold co-integration

To capture the dynamic behaviour of market agents, which has the potential for non-linearities and asymmetries in the price adjustment process, the application of threshold co-integration models in market integration (MI) analysis has gained much momentum in recent research studies as the traditional models assume linearity and symmetric adjustment towards equilibrium (Abdulai, 2002; Abunyuwah, 2020; Blake & Fomby, 1997; Enders & Siklos, 2001). Following this notation, the threshold autoregressive model (TAR) and momentum autoregressive model (M-TAR) co-integration approaches as proposed by Enders and Siklos (2001) were employed. The threshold autoregressive model can be expressed as:

$$\Delta\boldsymbol{\mu}_t = \boldsymbol{I}_t\rho_1\boldsymbol{\mu}_t + (1-\boldsymbol{I}_t)\rho_2\boldsymbol{\mu}_{t-1} + \sum\nolimits_{i=1}^{p}\gamma\Delta\boldsymbol{\mu}_{t-1} + \boldsymbol{\omega}_t \quad (1)$$

Where $\boldsymbol{I}_t$ is the Heaviside indicator function such that

$$\boldsymbol{I}_t = \begin{cases} 1 \;\; if \;\; \boldsymbol{\mu}_t \geq \tau \\ 0 \;\; if \;\; \boldsymbol{\mu}_t < \tau \end{cases} \quad (2)$$

where τ is the value of the threshold and ω_t is a sequence of zero-mean, constant variance independent identically distributed random variables, such that ω_t is is independent of $\boldsymbol{\mu}_t$. However, when the Heaviside indicator depends on the change in $\boldsymbol{\mu}_{t-1}$,

$$\boldsymbol{I}_t = \begin{cases} 1 \;\; if \;\; \boldsymbol{\mu}_{t-1} \geq \tau \\ 0 \;\; if \;\; \boldsymbol{\mu}_{t-1} < \tau \end{cases} \quad (3)$$

where $\boldsymbol{\mu}_t$ series exhibits 'momentum' in one direction. The τ value is usually set to zero in most economic applications such that the co-integrating vector coincides with the attractor. However, in an economic sense, there is no justifiable reason to expect the threshold to coincide with the attractor; thus, it is necessary to estimate the threshold value (τ). Thus, Chan's (1993) methodology which yield a super-consistent estimate of the threshold by minimizing the sum squared of errors was adopted.

2.2. Transmission dynamics of price linkages

Asymmetric effects may appear in series that are economically interconnected. In order to determine whether market players react differently to positive and negative shocks towards long-run equilibrium, the Hansen and Seo (2002) (HS) test was conducted to examine the presence of a significant threshold co-integration effect. Following the HS[1] test of the threshold effect, if the null hypothesis of the symmetric effect is rejected, the threshold error correction model (TVECM) is adopted. Thus, the threshold vector error correction model can be expressed as

$$\Delta \boldsymbol{P_t} = \begin{cases} \rho_1 \gamma' \boldsymbol{P_{t-1}} + \theta_1 + \sum_{\boldsymbol{m}=1}^{\boldsymbol{M}} \circledast_1 \triangle \boldsymbol{P_{t-m}} + \varepsilon_t, \;\; \gamma' \boldsymbol{P_{t-1}} \leq \boldsymbol{\Psi}(Regime1) \\ \rho_2 \gamma' \boldsymbol{P_{t-1}} + \theta_2 + \sum_{\boldsymbol{m}=1}^{\boldsymbol{M}} \circledast_{2\boldsymbol{m}} \triangle \boldsymbol{P_{t-m}} + \varepsilon_t, \boldsymbol{\Psi} < \gamma' \boldsymbol{P_{t-1}}(Regime2) \end{cases} \tag{4}$$

The TVECM model explains price changes due to price shocks in both the short and long terms but depends on the magnitude of the deviation from the long-term equilibrium. If there is asymmetric path of adjustment where $\gamma' \boldsymbol{P_{t-1}} \leq \boldsymbol{\Psi} < \gamma' \boldsymbol{P_{t-1}}$ then we incorporate asymmetries by assuming that (x) has a different impact on (y) as

$$\Delta \mathbf{P_{yt}} = \sum_{\mathbf{h}}^{\mathbf{r}} \emptyset \mathbf{h} \boldsymbol{P}_{\mathbf{yt-h}} + \sum_{\mathbf{i}=0}^{\mathbf{s}} \boldsymbol{\alpha}^{+} \mathbf{P}^{+}_{\mathbf{xt-i}} + \sum_{\mathbf{j}=0}^{\mathbf{q}} \boldsymbol{\alpha}^{-} \mathbf{P}^{-}_{\mathbf{xt-j}} + \boldsymbol{\varepsilon}_{\mathbf{t}} \tag{5}$$

where P_y is the price level of the reference market and P_x is the price level of the other markets under study in relation to the reference market. From Equation (5), the test of the null hypothesis $\alpha^+ = \alpha^-$ provides information about the impact of Px^+ and Px^- on Py, which specifies asymmetric or symmetric paths towards long-run. The distributed lag effect due to the impact of Px^+ and Px^- at any lag was examined by testing the null $\alpha_i^+ = \alpha_j^-, i = 1 \ldots s, j = 1 \ldots q,$ which, if rejected (not rejected), denotes an asymmetric or symmetric distributed lag effect. The cumulative symmetric and asymmetric effects of Px^+ and Px^- at lag $t-k$ were also examined by testing *for* $\sum_{i=k}^{s} \alpha_i^+ = \sum_{j=k}^{q} \alpha_j^-$ *with* $K \in [0, \min(s, q)]$ (Kang et al., 2018)

In summary, the analytical framework adopted in this study follows the following estimation process: the data-generating process of the series was analyzed using unit root tests and the Johansen co-integration test to estimate the co-integrating regression. The lagged estimated residuals from the co-integrating regression were then employed to specify the error-correction terms used in the specification of both the TAR and M-TAR models. Finally, the threshold error correction models were estimated, and the corresponding hypothesis tests were conducted. The study adopted the Box-Ljung test as indicated as (LB) to test autocorrelations of the residuals and fitness of the time series model.

3. Results and discussion

3.1. Descriptive analysis of price data

Price trend analysis helps to predict the responds of market intermediaries to future movement of a price changes. Figure 1 showed the visual plot of the monthly wholesale prices of onion from January 2011–December 2018 across all regional markets considered. The prices were characterized by fluctuations with a rise in price of onion which begun around 2013 which was as a result of onion supply crisis due to late monsoon rains accompanied by the poor performance of the Indian rupees leading to high inflation rate during the season.

The descriptive statistics of the seasonally unadjusted nominal prices of onions across the major markets under consideration are presented in Table 1. The results indicated that, across the spatially separated market, the highest nominal wholesale price was observed in the Kozhikode market with a maximum value of ₹ 7200/100 kg whereas the minimum price of ₹ 211 was recorded in Lasalgaon market.

From the results, the highest average wholesale price of ₹ 1512.5 was observed in Lucknow market with the lowest average wholesale price of ₹ 1260 observed in Mysore market. The minimum price in Lasalgaon was expected as the market receives the highest volume of onion arrival in the area as

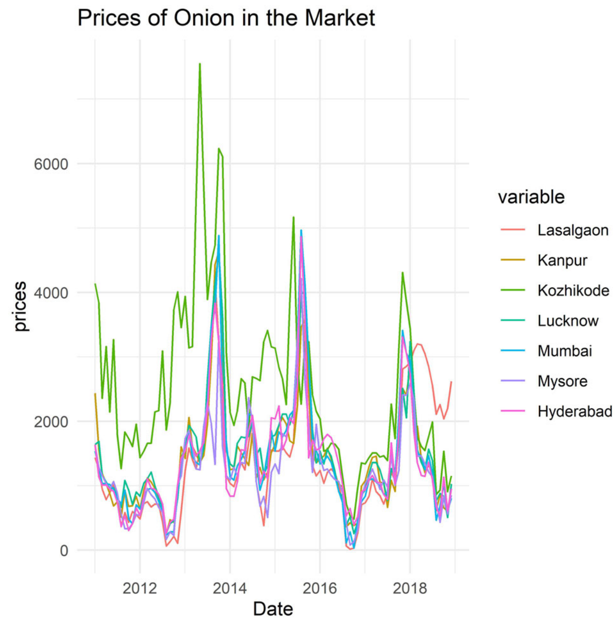

Figure 1. Plot of monthly prices of major onion markets in India.

Table 1. Descriptive statistics of prices of major onion markets in Rupees (₹).

	Lasalgaon (₹)	Kanpur (₹)	Kozhikode (₹)	Lucknow (₹)	Mumbai (₹)	Mysore (₹)	Hyderabad (₹)
Minimum	211.0	500.0	900	600	480.0	400	400
1st Qua	637.5	900	1300	897.0	750	800	800
Median	1000.5	1150	2100	1300	1050	1000	1164
Mean	1399.5	1420	2535	1512.5	1441	1260	1410
3rd Qua	2137.5	1562	3225	1650	1625	1540	1700
Maximum	4600.0	5200	7200	5200	5500	4750	5400

Table 2. Results unit root test.

			Test value		Critical value	
Markets	Deterministic term	Lags	Level	Difference	1%	5%
Lasalgaon	Trend	2	−3.20	−7.00	−4.04	−3.45
Kanpur	Trend	3	−3.04	−6.32	−4.04	−3.45
Kozhikode	Trend	1	−3.73	−9.67	−4.04	−3.45
Lucknow	Trend	1	−3.89	−6.41	−4.04	−3.45
Mumbai	Trend	1	−3.72	−6.31	−4.04	−3.45
Mysore	Trend	2	−3.45	−7.86	−4.04	−3.45
Hyderabad	Trend	2	−3.52	−7.81	−4.04	−3.45

literature points out that Maharashtra is the leading producer of onions in India with Lasalgaon as the major producing market unlike Mumbai, which is considered a consumption center (Ujjwal et al., 2017). Thus, further analysis was conducted with Lasalgaon in Maharashtra as the reference market.

3.2. Univariate analysis: unit root test

Prices for agricultural products fluctuate and follow distinct seasonal trends that reflect the varied marketing strategies used by farmers and market intermediaries as well as the production's inherent biological lag processes. Therefore, the price series was decomposed and seasonally adjusted before further analyses were conducted. Table 2 presents the results on the evaluation of the univariate data generating process (DGP) of the seasonally adjusted prices through the framework of the augmented Dickey- Fuller (ADF) test.

The results of the test statistic failed to reject the null hypothesis of a unit root at level for all the markets under study. However, the null hypothesis was rejected at 1percent significance level after the first differential implying that the markets were integrated of the same order and thus, share common long-run dynamic stochastic dynamic processes.

Table 3. Johansen test of cointegration.

Hypotheses	Test statistics (trace statistics)	Critical values	
		1%	5%
r<=6	7.40	16.26	12.25
r<=5	16.85	30.54	25.32
r<=4	39.15	48.45	42.44
r<=3	69.20	70.05	62.99
r<=2	102.72**	96.58	87.31
r<=1	154.51**	124.75	114.90
r=0	226.46***	158.49	146.76

*, **, *** indicate 10%, 5% and 1% level of significance respectively.

3.3. Co-integration analysis

The approach of testing the integration of spatially separated markets is based on the fact that deviations from the equilibrium conditions of the two or more non-stationary variables should be stationary. This implies that while price series may wander extensively, pairs should not diverge from one another in the long run (Abdulai, 2002). Thus, the multivariate co-integration rank between the spatial markets was estimated using Johansen's methodology. The result of the Johansen co-integration test is presented in Table 3.

The results revealed that all the markets under study share a common long-run dynamic process as the rank of no co-integration (r = 0) was rejected. This provides the existence and evidence of a common domestic and efficient onion market in India where inter-market prices adjust to achieve long-run market equilibrium. This result confirms a study conducted by Ahmed and Singla (2017) who reported an integrated of major onion markets in India. However, Johansen's traditional co-integration approach implicitly assumes a symmetric adjustment mechanism, which may not be realistic owing to technological progress, changes in people's preferences, economic crises, policy or regime alteration, and institutional development, and thus, has low power in the presence of asymmetric adjustment (Atil et al., 2014; Borenstein et al., 1997). However, further analysis that incorporates asymmetric and non-linear stochastic effects was studied in the next section.

3.3.1. Threshold and asymmetric co-integration modelling

In this section, we test for possibilities of asymmetric adjustments and threshold co-integration (non-linearity), other than assuming symmetric and linear relations, as in the case of traditional econometric approach to market integration and price dynamics. In this regard, the threshold autoregressive (TAR) and momentum threshold autoregressive (M-TAR) models and their extensions with asymmetric adjustment, as proposed by Enders and Siklos (2001) as specified in Equations 1–3 were estimated to examine whether the prices of the markets under study exhibit threshold co-integration and asymmetric adjustment. The results for the TAR and M-TAR models and their extended models are presented in Tables 4A and 4B, respectively.

From the results of M-TAR and its extension consistent M-TAR, the null hypothesis of no co-integration ($\rho 1 = \rho 2 = 0$) was rejected at the 5 percent significance level for all market pairs, indicating non-linear dynamic process. After confirming the co-integration between the market pairs under consideration, the null hypothesis of no asymmetry ($\rho 1 = \rho 2$) was also examined. Focusing on the Consistent M-TAR (Tables 4A and 4B), all the market pairs exhibited asymmetric adjustment in the long run as compared to earlier studies on onion markets in India (Ahmed & Singla, 2017; Gummagolmath & Rajalaxmi, 2019) who reported co-integration but could not account for whether the adjustments are asymmetric by simply assuming symmetry in the modelling approach. Moreover, the point estimates for the Lasalgaon – Kanpur market relationship were found to be $\rho 1 = -0.072$ and $\rho 2 = -0.368$ suggesting convergence at approximately 7 percent of the positive deviation and 36.8 percent of the negative deviation from the equilibrium were eliminated within one month. However, since $|\rho 1| < |\rho 2|$, implies that the markets exhibit little adjustment for a positive perturbation as compared to substantial decay for a negative shock signifying higher speed of adjustment towards long-run equilibrium takes place when the price spread diverges below the equilibrium. This result supports a study conducted by Karthick et al. (2022)

Table 4A. Threshold and asymmetric co-integration in onion market.

	Lasalgaon – Kanpur				Lasalgaon – Kozhikode				Lasalgaon – Lucknow			
Parameters	TAR	MTAR	CTAR	CMTAR	TAR	MTAR	CTAR	CMTAR	TAR	MTAR	CTAR	CMTAR
τ	0	0	−0.355	−0.130	0	0	0.715	−0.302	0	0	−0.216	0.074
$\rho 1$	0.064	−0.063	−0.072	−0.038	−0.047	−0.066	−0.027	0.055	−0.040	0.002	−0.013	0.032
	[0.464]	[0.545]	[0.371]	[0.672]	[0.490]	[0.358]	[0.711]	[0.328]	[0.641]	[0.985]	[0.874]	[0.772]
$\rho 2$	−0.363**	−0.258**	−0.460***	−0.368**	−0.186**	−0.159**	−0.180**	−0.332**	−0.352**	−0.257***	−0.454***	−0.245**
	[0.002]	[0.008]	[0.000]	[0.001]	[0.012]	[0.028]	[0.008]	[0.002]	[0.004]	[0.008]	[0.000]	[0.008]
$\rho 1 = \rho 2 = 0$	5.334**	3.765**	6.693**	5.958**	3.436**	2.791*	3.652**	5.573**	4.459**	3.717**	7.334***	3.951**
	[0.006]	[0.027]	[0.002]	[0.004]	[0.037]	[0.067]	[0.030]	[0.005]	[0.014]	[0.028]	[0.001]	[0.028]
$\rho 1 = \rho 2$	5.195**	2.225	7.760***	6.371**	2.154	0.928	2.566	6.218**	5.400**	3.968**	10.942***	4.421**
	[0.025]	[0.139]	[0.007]	[0.013]	[0.146]	[0.338]	[0.113]	[0.014]	[0.022]	[0.049]	[0.001]	[0.038]
LB(4)	0.443	0.428	0.464	0.480	0.753	0.772	0.870	0.644	0.612	0.595	0.793	0.623
LB(8)	0.399	0.275	0.407	0.423	0.824	0.795	0.906	0.792	0.577	0.539	0.699	0.477

*, ** indicate 10% and 5% level of significance. Values in brackets are the probability levels of the estimates.

Table 4B. Threshold and asymmetric co-integration in onion market.

	Lasalgaon – Mumbai				Lasalgaon – Mysore				Lasalgaon – Hyderabad			
Parameters	TAR	MTAR	CTAR	CMTAR	TAR	MTAR	CTAR	CMTAR	TAR	MTAR	CTAR	CMTAR
τ	0	0	0.175	0.255	0	0	0.325	0.221	0	0	0.213	0.019
$\rho 1$	0.003	−0.080	0.009	0.161	−0.098	−0.275*	−0.099	−0.265*	−0.051	−0.110	−0.033	−0.079
	[0.976]	[0.415]	[0.916]	[0.309]	[0.346]	[0.035]	[0.319]	[0.056]	[0.535]	[0.239]	[0.680]	[0.348]
$\rho 2$	−0.349**	−0.125	−0.36**	−0.153*	−0.291**	−0.096	−0.340**	−0.116	−0.225**	−0.120	−0.282**	−0.173*
	[0.005]	[0.239]	[0.006]	[0.058]	[0.031]	[0.371]	[0.021]	[0.265]	[0.035]	[0.199]	[0.011]	[0.100]
$\rho 1 = \rho 2 = 0$	4.146**	0.930	4.015**	2.700*	2.580*	2.460*	2.943*	3.143**	2.362*	1.391	3.353**	2.654*
	[0.019]	[0.398]	[0.021]	[0.073]	[0.081]	[0.091]	[0.058]	[0.048]	[0.100]	[0.254]	[0.039]	[0.076]
$\rho 1 = \rho 2$	6.416**	0.108	6.159**	3.581*	1.560	1.329	2.258	0.882	1.891	0.008	3.814*	0.609
	[0.013]	[0.398]	[0.015]	[0.062]	[0.215]	[0.252]	[0.136]	[0.350]	[0.173]	[0.930]	[0.054]	[0.437]
LB(4)	0.780	0.744	0.760	0.829	0.938	0.569	0.950	0.884	0.988	0.975	0.983	0.879
LB(8)	0.644	0.543	0.638	0.544	0.175	0.258	0.209	0.101	0.863	0.785	0.881	0.732

*, **, *** indicate 10%, 5% and 1% level of significance respectively. Values in brackets are the probability levels of the estimates.

Table 5. Hansen-Seo test of threshold cointegration.

Market Pairs	Sup-LM stat	Critical values
Lasalgaon-Kanpur	38.75*	36.78
Lasalgaon-Kozhikodde	14.98*	13.90
Lasalgaon-Lucknow	23.58*	23.24
Lasagaon-Mumbai	22.89*	19.68
Lasalgaon-Mysore	21.04*	18.76
Lasalgaon-Hyderabad	14.98**	12.41

*, ** indicate 10% and 5% level of significance.

that reported long-run stochastic dynamic process among major onion markets in India but at a very slow pace of adjustment towards long run equilibrium level. In other words, price increases are persistent and tend to revert back to the attractor less rapidly, but decreases tend to revert quickly towards the long-run equilibrium. This implies that 93 percent and 63.2 percent of positive and negative deviations from the equilibrium would persist in the market for the following months, respectively. This adjustment process signifies that wholesalers respond much more quickly to shocks that squeeze profit margins than to those that stretch them. The asymmetric adjustment in the market can be attributed to the fact that the determination of price is heavily influenced by the trader's associations rather than the true auction of demand and supply effects normally associated with free trade as Lasalgaon serves as the producer market where majority of production takes place. The wholesalers form tacit cartel under the influence of association leaders, which gives them much market power to regulate the price and volume of sales in a specific period. This phenomenon in the market suggests that increase in wholesale prices in the reference market is transmitted more rapidly to other regional markets than price reductions. When a threshold co-integration model is estimated, it is crucial to examine whether the nonlinear model (threshold effect) is significant. In view of this consideration, Hansen and Seo (2002) test was employed to ascertain the presence of significant threshold dynamic adjustments. The grid search for the threshold value (λ) was conducted over 60 grid points with the fixed regressor bootstrap experiments used to calculate the p-values for the SupLM test. The results are presented in Table 5.

Based on the sup-LM test statistics, the results indicated that the market pairs exhibit threshold co-integration. This implies that price adjustment will only occur when the price levels exceed certain level to create arbitrage for the market players to shift the commodity from a glut/surplus center to a deficit place. Thus, the asymmetric threshold vector error correction model as specified in Equation 4 and 5 was estimated to examine the long-run and short-run transmission dynamic processes.

3.4. Asymmetric price transmission dynamics in onion markets in India

In this section, we studied the price transmission dynamics of onion market prices by employing an asymmetric threshold vector error correction model (TVECM). The results are presented in Table 6. The results for the Lasalgaon - Mumbai market relationship through the search procedure yielded a threshold parameter of $\gamma = 0.175$, which can be expressed as the short-term elasticity price. Calculated at average prices using the short-run term elasticity, this deviation represents roughly ₹ 252.16/100 kg and ₹ 244.91/100 kg in the Mumbai and Lasalgaon markets respectively. Thus, if the deviations from long-term equilibrium are below these prices in both markets, no adjustment will occur. The point estimate revealed that when the deviation is set above these prices, the speed of adjustment toward equilibrium by the Mumbai wholesaler (ϕ^{Mumbai} =-0.170) is 17 per cent. This finding implies that positive deviation tends to persist for a long period in the market.

This behaviour has ramification on farmers as any intervention that seeks to increase the profit margin of the farmers and squeezes the profit margin of the wholesaler takes a long time to be transmitted. Ahmed and Singla (2023) noted these inefficiencies in market price transmission process can be attributed to infrastructure and communication and differences in marketing fees, taxes, commission charges, license fees across the spatially separated agricultural markets in India. This study results, however, reveal that the short-run dynamics of prices in Mumbai are influenced by its own prices and price deviation in Lasalgaon, but the path of short-run causality is asymmetric.

Furthermore, the Kanpur market in relation to the referenced market responded to both positive and negative discrepancies in the long-run price equilibrium created by the price divergence in Lasalgaon market. In the Kanpur market, we observed a faster adjustment response behaviour of the wholesalers to negative deviations towards equilibrium compared to positive deviations, implying positive asymmetry, whilst Mysore market agents exhibited faster adjustment to positive perturbation to negative deviation. The point estimates of the adjustment parameters imply that Kanpur market agents adjusted to eliminate about 28.4 percent of prices change above the threshold value (positive deviation) and 36.6 percent of the change in the deviation below the threshold. However, Mysore market middlemen adjust to eliminate 37.6 percent of positive deviation whilst market intermediaries at Lucknow adjust to eliminate 31.9 percent of the negative deviation from the equilibrium relationship created by changes in the Lasalgaon prices. The results revealed a distributed lag asymmetric effect for Lasalgaon on its own price and an asymmetric effect on the Kanpur, Korzhikode, Lucknow, and Mysore markets. The results revealed that the Kanpur, Lucknow, and Mumbai markets were likely to exhibit an asymmetric path of adjustment towards equilibrium in the long-run to price changes created by Lasalgaon prices implying differences in response to price increase and decrease, whereas Korzhikode exhibited a symmetric path of adjustment to equilibrium.

Calculated in time response when deviation between Lasalgaon – Hyderabad market is below the threshold ($\tau = 0.213$) or ₹ 300.33/wholesalers take approximately 1.44 months to respond to the price changes but increase in price levels takes approximately 4.67 months for producer to benefit from the price increase. The results, moreover; indicated that the short-run price dynamics in Hyderabad are influenced by the conduct of wholesales in Hyderabad as well as the behaviour of wholesalers in Lasalgaon, but the long-run and short-run adjustment paths towards equilibrium are characterized by asymmetric transmission.

In order to further explore the behaviour of the middlemen, a regime switch analysis was conducted to examine the probability of the decay process of perturbation. The results depicted in Table 7 revealed that all wholesalers in the markets respond to deviations that seek to increase their profit margin compared to deviations that seek to increase the profit that is likely to improve the livelihood of the producers (farmers).

Table 6. Price transmission dynamics in onion market.

	ΔP_{Lasa}	ΔP_{Kanpur}	ΔP_{Lasa}	$\Delta P_{Kozhikode}$	ΔP_{Lasa}	$\Delta P_{Lucknow}$	ΔP_{Lasa}	ΔP_{Mumbai}	ΔP_{Lasa}	ΔP_{Mysore}	ΔP_{Lasa}	$\Delta P_{Hyderabad}$
Ect^{+}	0.055 (0.186)	−0.284* (0.144)	−0.337** (0.190)	0.142 (0.185)	0.145 (0.198)	−0.156 (0.155)	0.008 (0.246)	−0.170* (0.091)	0.030 (0.231)	−0.376 (0.140)*	0.127 (0.201)	−0.148 (0.198)
Ect^{-}	−0.230** (0.112)	−0.366** (0.166)	0.024 (0.079)	−0.192** (0.07)	−0.179 (0.136)	−0.319** (0.106)	0.044* (0.011)	−0.231** (0.105)	0.072 (0.200)	−0.148 (0.208)	−0.105 (0.107)	−0.309 (0.105)***
$H_{01}: Ect^{+} = Ect^{-}$	1.525 [0.220]	0.211 [0.647]	3.083* [0.08]	2.799** [0.09]	2.055 [0.155]	0.842 [0.361]	0.040 [0.842]	0.251 [0.618]	0.014 [0.906]	0.393 [0.532]	1.108 [0.296]	0.548 [0.461]
ΔLA_{t-1}	0.231** (0.134)	0.225** (0.103)	0.373** (0.109)	0.183** (0.107)	0.240** (0.128)	0.182* (0.102)	0.046 (0.137)	0.138 (0.128)	0.331** (0.133)	0.413** (0.139)	0.248** (0.124)	0.331*** (0.123)
ΔLA_{t-2}	−0.250 (0.138)**	−0.103 (0.107)	−0.197* (0.105)	0.060 (0.103)	−0.279** (0.128)	0.018 (0.101)	−0.284** (0.126)	−0.134 (0.129)	−0.223* (0.129)	−0.035 (0.135)	−0.378** (0.125)	−0.226* (0.124)
ΔKA_{t-1}	0.202 (0.165)	0.122 (0.128)										
ΔKA_{t-2}	0.055 (0.150)	0.268** (0.116)										
ΔKOZ_{t-1}			−0.030 (0.127)	−0.087 (0.124)								
ΔKOZ_{t-2}			0.162 (0.115)	−0.057 (0.113)								
ΔLU_{t-1}					0.230 (0.161)	0.175 (0.127)						
ΔLU_{t-2}					0.135 (0.155)	0.065 (0.122)						
ΔMU_{t-1}							0.530** (0.152)	0.311** (0.143)				
ΔMU_{t-2}							0.106 (0.156)	0.099 (0.146)				
ΔMY_{t-1}									0.031 (0.147)	−0.881* (0.124)		
ΔMY_{t-2}									0.095 (0.131)	−0.017 (0.137)		
ΔHY_{t-1}											0.154 (0.136)	0.093 (0.134)
ΔHY_{t-2}											0.350*** (0.129)	0.203** (0.197)
$H_{02}: \sum_{i=1}^{2} \alpha_i^{+} = \sum_i^2 \alpha_i^{-}$	0.627 [0.431]	0.365 [0.547]	0.004 [0.950]	1.519 [0.221]	1.219 [0.273]	5.310** [0.024]	0.189 [0.665]	2.419 [0.124]	0.241 [0.625]	1.541 [0.218]	0.551 [0.460]	1.790 [0.185]
$H_{03}: \sum_{i=1}^{2} \beta_i^{+} = \sum_i^2 \beta_i^{-}$	1.981 [0.163]	0.291 [0.591]	0.616 [0.435]	3.052* [0.084]	0.723 [0.398]	1.851 [0.177]	0.377 [0.541]	1.062 [0.306]	0.134 [0.716]	0.983 [0.324]	0.477 [0.492]	1.192 [0.278]
Causality: $X \rightarrow Y$	3.496** [0.03]	3.076**[0.05]	6.413** [0.003]	1.998* [0.10]	4.239** [0.018]	1.665 [0.195]	2.796* [0.067]	1.450 [0.240]	4.507** [0.014]	4.447** [0.015]	6.371*** [0.003]	5.196*** [0.007]
Causality: $Y \rightarrow X$	0.750 [0.475]	2.652* [0.07]	1.051 [0.354]	0.346 [0.709]	1.233 [0.296]	1.010 [0.368]	6.093** [0.003]	2.416* [0.095]	0.277 [0.759]	0.887 [0.415]	3.848* [0.028]	1.346 [0.266]

*,**,*** indicate 10%, 5% and 1% level of significance respectively. Values in brackets are the probability levels of the estimates.

Table 7. Detection of regime switch.

Transition matrix		
	To negative shock	To positive shock
From negative shock	0.965	0.035
From positive shock	0.100	0.900
Response		
	Regime 1	Regime 2
Kanpur	0.147	0.484
Korzhikode	0.109	0.624
Lucknow	0.05	0.633
Mumbai	0.534	0.767
Mysore	0.264	0.300
Hyderabad	0.163	0.168

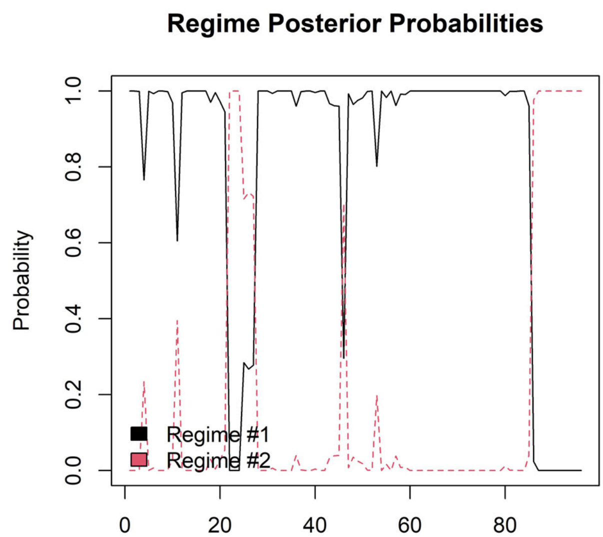

Figure 2. Regime posterior probabilities.

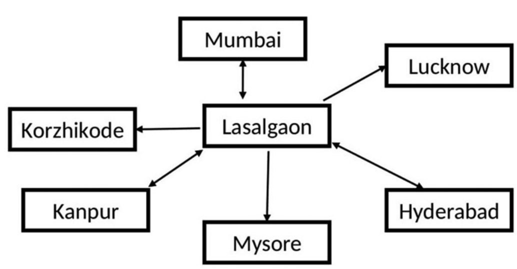

Figure 3. Causal relationship among major onion markets under study.

All the markets under present study exhibited an asymmetric path of adjustment towards long-run equilibrium with faster adjustment for negative shocks than for positive shocks, as depicted by the regime switch transition probability matrix (Table 7 and Figure 2).

A Granger causality test was conducted as presented in Figure 3 to examine the direction of transmission. The test results revealed a mixed pattern of both bidirectional and unidirectional causality running from Lasalgaon to the other markets. The results revealed bidirectional causality between Lasalgaon, Hyderabad, Mumbai, and Kanpur, and unidirectional causality running from the referenced market (Lasalgaon) to Korzhikode, Lucknow, and Mysore.

Conclusion

The study focused on the analysis of market integration and price transmission dynamics through the framework of non-linear modelling approach to provide more information about price dynamics, and behaviour of market players and performance of onion markets in India. Momentum threshold autoregressive model was employed to examine the degree of spatial market integration among major onion markets in India. The transmission dynamics process was analysed through non-linear threshold models with an application of an extension of new categories of asymmetries such as the distributed lag effect, cumulative impact, reaction time, and momentum equilibrium adjustment paths. The results of the estimation procedures revealed that the onion markets under present study were characterized by distinct threshold co-integration and asymmetric adjustment processes, both in the short and long run. The results suggested that wholesalers respond swiftly to deviations that tend to increase their profit margin than perturbations that intend to increase the benefit of the consumer rupee to the farmer. This behaviour of middlemen has a serious effect on the livelihood of producers as price changes that seek to benefit the farmers are transmitted at a lower rate whilst consumers suffer the rapid positive transmission process which may affect the nutritional security of poor family households. This asymmetric behaviour could be due to the strong tacit cartel power of the wholesaler's collision activities or political interference in the market. Given the results of the study, we recommended stringent measures against intensification of existing regulated marketing structures that seek to favour middlemen at the expense of producers and consumers and improvement in market intelligence structure for efficient conduct and performance of the onion markets in India. We, however, suggest that further studies should focus on inter-band adjustment process to further understand the dynamic process in agricultural market price transmission for better policy formulation.

Note

1. For comprehensive and detailed notes on HS test see Hansen and Seo (2002). Testing for Two-Regime Threshold Co-integration in Vector Error-Correction Models.

Author contributions

James K. Blay and Akshata Nayak conceptualized, designed and collected data for the research study. James Kofi Blay, in addition analysed the data, and wrote the first draft of the manuscript. Isaac Abunyuwah wrote the R codes for the graphics and the econometric models for the revised version of the manuscript. Huchaiah Lokesha and Gracy Chennothumalil Paily critically reviewed and approved the final version of the manuscript

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Data availability statement

The data that support the findings of this study are available in Agmarknet at https://agmarknet.gov.in/. However, other materials including R-codes used for analysis would be made available upon request from the authors.

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