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Price transmission behaviour of major seed spices in Rajasthan

Kailash Chand Bairwa[1*], G L Meena[2], Hari Singh[2], Harkesh Kumar Balai[3], Anju Yadav[3] & P C Meena[4]

[1]*Department of Agricultural Economics, College of Agriculture, Agriculture University, Jodhpur, Baytu, Barmer, Rajasthan.*

[2]*Department of Agricultural Economics and Management, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan.*

[3]*Department of Agricultural Economics and Management, RCA, Udaipur, Rajasthan.*

[4]*Department of Agricultural Economics, College of Agriculture, Agriculture University, Jodhpur, Sumerpur, Pali, Rajasthan.*

**E-mail: kailashiari@gmail.com*

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Abstract

The present study was based on secondary price information. The study period from January, 2011 to December 2021 was chosen to analyse the price behaviour of major seed spice markets in Rajasthan. The data was analysed using the Augmented Dickey Fuller (ADF) test and Vector Error Correction Model to accomplish the objectives of the study. ADF test results showed that price data for coriander, cumin, fenugreek, and fennel were non-stationary at the level and stationary at the first difference level. Values of trace and maximum Eigen of Johansen multiple co-integration tests revealed three co-integration equations in cumin and coriander crops, but only one co-integration equation in fennel prices. Prices of coriander, cumin, and fennel in selected KUMS (Krishi Upaj Mandi Samiti) were primarily influenced by the one-month and two-month lag prices of respective markets in the long run. The prices of coriander, cumin and fennel demonstrated one-way co-integration in KUMS, Merta City→KUMS, Jodhpur and Ramganj Mandi→Baran while combination of Baran↔Kota, Ramganj Mandi↔Kota and Merta City↔Niwai showed bi-directional co-integration. Fenugreek prices in selected KUMS did not move in tandem over a long period of time. We find that the prices of coriander, cumin and fennel in Rajasthan's selected markets moved in lockstep over time and were influenced by one month or two months lag price of other respective markets.

Keywords: Price behaviour, seed spices, coriander, cumin, fennel, Johansen's multiple co-integration, Augmented Dickey Fuller Test.

Introduction

Indian spices are popularly known for their flavour and aroma all over the world (Verma & Kumar, 2015). India is renowned as the "Home of Spices," as it is the world's largest producer, consumer, and exporter of spices (Bairwa *et al.*, 2022). About 75 species of 109 spices are grown in the country. Out of these 16 spices are essential, including black pepper, cardamom, ginger, turmeric, clove, chilli, garlic, saffron, celery, cumin, coriander, fennel, fenugreek, ajwain, dill and nigella (RSAMB, 2010). A group of crops that include coriander, cumin, fennel, fenugreek aniseed, dill, celery, nigella and caraway are called seed spices. Seed spices are annual herbs that are used as spices in the form of dried seeds or fruits. Seed spices are utilized in a variety of indigenous remedies, nutraceuticals, pharmaceuticals, aromatherapy, natural colours, drinks, preservatives, botanicals, and insecticides, in addition to flavour and scent. During 2019-20, total exported quantity and value of spices were 11.83 lakh tons and ₹2151.5 thousand lakh respectively. Seed spice demand is on the rise, and importing countries are looking to India as a reliable source of supply. Though seed spices are extensively traded, their production is unpredictable and fluctuates from year to year due to weather aberrations and the incidence of a variety of diseases such as wilt, downy mildew and blight.

In the year 2019, Asian countries contributed approximately 94 per cent of the world's spice production, with India accounting for 69 per cent of the total (FAOSTAT, 2019). During 2019-20, approximately 101.26 lakh ton spices were produced from 43.18 lakh hectare area under various spice crops in India. The seed spices output was 19.41 lakh tons from 20.19 lakh hectare area in the same year (Spices Board of India, 2019-20). The arid and semi-arid states of Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh, and Andhra Pradesh form the main belt of these seed spice crops in India. Rajasthan and Gujarat states collectively contributed approximately 70 per cent of total seed spice production in the country, winning them the term "Bowl of Seed Spices" (Spice Board of India, 2019-20). Rajasthan has the highest area and production of spices as well as seed spices in India. In Rajasthan, seed spices are mostly grown in arid and semi-arid conditions, and these crops provide a living and employment to a large number of farmers. The area under total spice cultivation in Rajasthan in 2019-20 was 10.20 lakh hectares, with a production of 10.59 lakh tons, while the area and production under seed spices were 9.19 lakh hectare and 6.09 lakh tons, respectively (Spice Board of India, 2019-20). More than 70 per cent of seed coriander comes from Rajasthan's *Hadoti* region, which includes the districts of Kota, Baran, Bundi, and Jhalawar (Verma, 2017). Similarly, more than 90 per cent cumin and 50 per cent fenugreek are produced in Rajasthan's dry western region, which includes the districts of Jodhpur, Barmer, Jaisalmer, Bikaner, Churu, Jalore and Nagaur (Meena *et al.* 2020).

In order to develop a sound price policy for seed spices in India, it is necessary to analyse price performance over time and space. Such analysis is beneficial to spice growers in determining the best time to sell their produce and maximise profits. In light of numerous policy changes at the regional, national, and even international levels, it is important to analyse the market price behaviour of seed spice sector especially in Rajasthan, which formed the objective of the study.

Materials and methods

The present research study is based on secondary information on price of seed spices in Krishi Upaj Mandi Samities (KUMS) of Rajasthan, based on arrivals of selected seed spices in triennium ending 2015-17. Based on arrivals of spices in KUMS, three KUMS with highest arrivals were selected for each seed spice crop as under:

Table 1. Selected KUMS and their share in market arrivals quantity for major seed spice crops in Rajasthan

Seed spice	Krishi Upaj Mandi Samiti					
	KUMS	Share in arrivals qty (%)	KUMS	Share in arrivals qty (%)	KUMS	Share in arrivals qty (%)
Coriander	Ramganj Mandi	42.12%	Kota	24.27%	Baran	17.01
Cumin	Jodhpur	33.65%	Merta City	20.00%	Nagaur	10.63%
Fennel	Nagaur	22.28%	Merta City	19.75%	Niwai	16.04%
Fenugreek	Bikaner	20.78%	Nokha	13.71%	Kota	24.16%

Analytical tools

The price differential between spatially separated market pairs during study period from January, 2011 to December, 2020 are discussed in the study. Before analysis of time series data, we used appropriate statistical technique for estimating missing data on prices. When the system operates in pairs of markets is unison then it represents market integration. There are various techniques to study the market integration *viz.,* (i) Johansen multiple co-integration test to find out the long run equilibrium among markets, (ii) Vector Error Correction Model (VECM) to capture the speed of adjustment to deviations in long run equilibrium, and (iii) Pair wise Granger Causality test to analyze the influence of prices of each market on all other markets. In the present study, all above techniques were used to work out the order of integration, short run & long run association, speed of adjustment to equilibrium and influence of prices of one market on others of the same commodity.

Before testing for co-integration, the time series data on monthly price has to be checked for its stationarity. If the actual time series data is having non-stationarity, then the first difference of the data series is computed and tested for its stationarity. Dickey Fuller (Dickey & Fuller, 1979) and Augmented Dickey- Fuller (Engle & Granger, 1987) tests are mostly used for testing unit roots or non-stationarity in time series data. Both are tested with the null hypothesis that the time series data has an unit root or not-stationarity. i.e.

H_0: There is non- stationarity in time series data

H_1: There is stationarity in time series data

The stationarity in the times series data were computed by performing the Augmented Dickey Fuller (ADF) test instead of Dickey Fuller test. The ADF test removes all autocorrelation in the secular time series data before computing non-stationarity using same procedure as Dickey Fuller test. This test was conducted on the variables at level (actual price data) and first differences (Dickey & Fuller, 1979). The Dickey Fuller test was used by following the regression equation.

$$\Delta Y_t = \beta_t + \delta Y_{t-1} + U_t$$

Where,

$\Delta Y_t = (Y_t - Y_{t-1})$ and $Y_t = \ln Y_t$

The Augmented Dickey Fuller test was applied with the following regression equation:

$$\Delta Y_t = \beta_t + \delta Y_{t-1} + \alpha_i + \sum_{i=1}^{n} \Delta Y_{t-1} + e_t$$

Where;

$\Delta Y_t = (Y_t - Y_{t-1})$and $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$

The ADF test procedure was most efficient to know whether prices of selected seed spices were integrated of same order or not at level. Because it identifies the number of co-integrating vectors between the non-stationary variables at level in the context of a Vector Error Correction Model.

Co-integration: co-integration is the conjunction between integration processes and steady state equilibrium. It provides relevant theoretical framework for examining non-stagnant of instantaneous changes in a pair of price series along with their valuable secular information. Here the original data was non-stationary and after converting them into first difference, the series became stationary. Johansen co-integration test (1988) was used to estimate the long run association among monthly price series. For applying Johansen co-integration test, data or variable must be non-stationary and integrated of the same order. This is a multivariate systematic equation approach, which is used for simultaneous adjustment of two or more variables. Johansen's approach has many advantages over the single equation method. First, it allows examining the co-integration vector with lesser variance. Secondly, it is not compulsory to assume exogeneity of either of the variables. The null hypothesis and alternative hypothesis for estimation of number of co-integration equations are varying according to cases.

(i) *None*

H_0: There is no co-integration equation. i.e. there is no co-integration among the variables.

H_1: There is co-integration equation

(ii) *At most 1*

H_0: There is at least one co-integration equation.

The null hypothesis is rejected when the P-value is less than 5 per cent. When the H_0 is not rejected, then the variables are not having long run association. It means, when the variables are co-integrated or associated in the long run, then we can apply Vector Error Correction Model (VECM).

Vector Error Correction Model (VECM): The vector error correction model can be used when there is long-run association among the variables. The use of an optimum lag value is also critical for the use of VECM. The VECM automatically converts variables to stationarity. If the price series are I (1), then one could run regression in their first differences. Nonetheless, by taking first differences, the long run relationship that is stored in the data is being lost. It means that one needs to use variables in levels as well. Advantage of the error correction model is that it incorporates variables both in their levels and first differences. By doing this, error correction model captures the short run dis-equilibrium as well as the long run equilibrium adjustments between prices. This model can include such short run and long run changes in the price movements. A generalized error correction model formulation to understand both long run and short run behaviour of prices can be considered by first taking the autoregressive distributed lag model equation as follows:

$$Y_t = a_{01}X_t + a_{11}X_{t-1} + a_{12}Y_{t-1} + \varepsilon_t$$

$$\Delta Y_t = a_{01}\Delta X_t + (1 - a_{12})\left[\frac{a_{01} + a_{11}}{1 - a_{12}} X_{t-1} - Y_{t-1}\right] + \varepsilon_t$$

The generalized equation of above function for k lags and an intercept term is as follows:

$$\Delta Y_t = a_{00} + \sum_{i=0}^{k-1} a_{i1}\Delta X_{t-1} + \sum_{i-1}^{k-1} a_{i2}\Delta Y_{t-1} + m_0[m_1 X_{t-k} - Y_{t-k}] + \varepsilon_t$$

Where;

$$m_0 = (1 - \sum_{i=1}^{k} a_{i2}), and \ m_1 = \frac{\sum_{i=0}^{k} a_{i1}}{m_0}$$

The parameters m_0 indicates the rate of adjustment of the short run deviations towards the long run equilibrium. Theoretically, this parameter varies between zero to one. The extent of 0 indicates no adjustment and 1 denotes an instantaneous adjustment. A range between zero to one represents that any deviations have steady adjustment to the long run equilibrium values.

For the present study, Johansen's Vector Error Correction Model (VECM) was used because it provides the testing of co-integration as a system of equations in one-step. Secondly, the model does not require carrying over an error from one-step into the rest. In addition, it does not require the prior assumptions of endogenity or exogenity of the variables. The co-integration among markets prices was computed by using E-VIEWS-7 version 7.0.0.1 software.

Results and discussion

Cumin: For the ADF models to be viable, the coefficient of variable at level data must be negative. In their study, Sinharoy & Nair (1994) found that the monthly spot price of pepper in India, Brazil, and Indonesia must have been stationary at the second difference during the study period. The Augmented Dickey Fuller test indicated that cumin price of KUMS, Jodhpur, Nagaur, and Merta City were stationary after first difference.

Johansen's multiple co-integration analysis: Table 2 presents the results of long run co-integration analysis for three KUMS: Jodhpur, Merta City, and Nagaur. It was revealed from the table that the value of trace statistic and maximum Eigen of the unrestricted integration rank test showed three co-integration equations at the 5 per cent level of significance throughout the entire study period. As a result, selected markets had long run co-integration for cumin prices in Rajasthan, implying that cumin prices in selected KUMS moved together over time.

The coefficients of the long run co-integration equation were used to represent the directions of movement in cumin prices. The negative coefficient value (-1.008036) of cumin price in KUMS, Merta City indicates that when the cumin price in Merta City falls, the cumin price in KUMS, Jodhpur will rise in the long run. In the case of KUMS, Nagaur, the coefficient value is positive (1.638080), indicating a positive relationship with KUMS, Jodhpur's cumin price. Bannor *et al.* (2016) found similar results for cumin co-integration analysis in Sojat Road, Merta City, Kekri, Bhagat Ki Kothi and Bhinmal markets of Rajasthan during 2008-2015.

Table 2. Results of Johansen's multiple co-integration analysis of cumin price

Hypothesized no. of CE(s)	Eigen value	Trace statistic	Critical value 0.05	*P-value***
None *	0.228156	58.12429	29.79707	0.0000
At most 1 *	0.179002	27.56554	15.49471	0.0005
At most 2 *	0.035718	4.291837	3.841466	0.0383

Trace test indicates 3 co-integrating equation @ 0.05 level
* denotes rejection of the hypothesis @ 0.05 level
**MacKinnon-Haug-Michelis (1999) *P-values*

	Coefficients of long run co-integration equation		
	Jodhpur	Merta City	Nagaur
Normalized co-integrating coefficients (standard error in parentheses)	1.000000	-1.008036 (0.10762)	1.638080 (0.32496)

The results indicate that cumin prices in KUMS, Jodhpur, Merta City, and Nagaur moved together in the long run. However, in the long run, the directions of movement in cumin prices at KUMS, Jodhpur were reported to have a positive and negative relationship with cumin prices at Nagaur and Merta City, respectively.

Vector error correction model: In the dynamic model, the VEC model is used to indicate the rate of adjustment among the factors before reaching saturation. Table 4 displays the results of the short run equilibrium of cumin price series computed using VECM. As per the table, KUMS, Merta City, and Nagaur were reported to be in short run equilibrium, as indicated by the rapid rate of adjustment and significance level. In the long run, the KUMS, Jodhpur cumin prices were influenced by one-month lag price of Merta City. The cumin prices at KUMS, Merta City were influenced by one-month lag price of its own and KUMS, Nagaur. At the same time, the cumin price of KUMS, Nagaur were influenced by their respective one-month lag price.

Table 3. Results of vector error correction model for cumin price in selected KUMS of Rajasthan

Error correction	D (J)	D (M)	D (N)
CointEq1	-0.027923	0.135359	-0.157197
	(0.04981)	(0.04655)	(0.05023)
	[-0.56055]	[2.90779]	[-3.12963]
D (J(-1))	-0.109310	-0.004755	0.106540
	(0.11563)	(0.10805)	(0.11659)
	[-0.94537]	[-0.04400]	[0.91382]
D (M(-1))	0.315798	0.239506	-0.242372
	(0.11809)	(0.11035)	(0.11907)
	[2.67424]	[2.17041]	[-2.03554]
D (N(-1))	-0.060606	-0.183469	-0.098501
	(0.09624)	(0.08994)	(0.09704)
	[-0.62972]	[-2.03998]	[-1.01503]

Standard error in ( ) and t-statistic in [ ]; J-Jodhpur, M-Merta City and N-Nagaur

As a consequence of the above analysis, it can be concluded that cumin prices in KUMS, Jodhpur, Merta City, and Nagaur were primarily influenced by the one-month lag cumin price of KUMS, Merta City, Rajasthan.

Pair wise Granger-causality test analysis: The Pair wise Granger Causality test is a component of the co-integration analysis of two variables. The results of the Pair wise Granger causality test for the existence of co-integration between selected combinations of two-cumin price markets are shown in Table 4. The P-value between cumin prices in KUMS, Merta City→KUMS, Jodhpur was less than 5 per cent, indicating that cumin price in KUMS, Merta City caused cumin price in KUMS, Jodhpur. Thus, only unidirectional co-integration was observed in the cumin prices of the KUMS, Merta City→KUMS, Jodhpur combination in Rajasthan. Charles *et al.* (2020) found a one-way relationship between red chilies prices at traditional markets and wholesalers in East Nusa Tenggara province, Indonesia, and no short run causality during the study period (2018-2019).

Table 4. Results of Pairwise Granger-causality of cumin prices in selected KUMS

Null hypothesis	Observations	*F-statistic*	*P-value*	*Direction*
M does not Granger Cause J	119	9.52324	0.0025	M→J
J does not Granger Cause M		0.40482	0.5259	-
N does not Granger Cause J	119	0.58284	0.4468	-
J does not Granger Cause N		0.33279	0.5651	-
N does not Granger Cause M	119	3.68682	0.0573	-
M does not Granger Cause N		0.05585	0.8136	-

M-Merta City, J-Jodhpur and N-Nagaur.

Therefore, it could be summarized from the above analysis that cumin prices combination of KUMS, Merta City→KUMS, Jodhpur in Rajasthan demonstrated one-way co-integration.

Coriander: The results of the Augmented Dickey Fuller test for KUMS, Ramganj Mandi, Kota, and Baran indicated that the price series of coriander were stationary at first difference. Furthermore, the coefficient of variable was found to be negative in all three forms of model. Therefore, the integration order was observed to be one. The results indicated that coriander prices series of KUMS, Ramganj Mandi, Kota and Baran were viable after first difference in all three models of Augmented Dickey Fuller test.

Johansen's multiple co-integration analysis: Table 5 presents the results of long run co-integration analysis in selected KUMS namely Kota, Ramganj Mandi, and Baran. The table showed that during the entire study period, the values of trace statistic and maximum Eigen of the Johansen's multiple co-integration test revealed three co-integration equations at the 5 per cent level of significance. Therefore, selected KUMS had a long run association for coriander prices in Rajasthan, *i.e.* coriander prices in selected KUMS moved together over time. The directions of movement in coriander prices, on the other hand, were reported by the coefficients of the long run co-integration equation. The negative coefficient value (-0.937034) of coriander price in KUMS, Ramganj Mandi indicates that when the coriander price in KUMS, Ramganj Mandi falls, the coriander price in KUMS, Kota will rise in the long run. In the case of KUMS, Baran, the coefficient value is ineffective (0.00000), indicating that there is no positive or negative relationship with the KUMS coriander prices. Sahu *et al.* (2019) found a long-run relationship between daily spot and future prices of chilli, turmeric, and cumin in India from October 2015 to April 2017.

Table 5. Results of Johansen's multiple co-integration analysis of coriander price

Hypothesized no. of CE(s)	Eigen value	Trace statistic	0.05 critical value	*P-value***
None *	0.311329	68.67610	29.79707	0.0000
At most 1 *	0.165561	25.03606	15.49471	0.0014
At most 2 *	0.032450	3.859587	3.841466	0.0495

Trace test indicates 3 co-integrating equation @ 0.05 level
 * denotes rejection of the hypothesis @ 0.05 level
 **MacKinnon-Haug-Michelis (1999) *P-values*

	Coefficients of long run co-integration equation		
	Kota	Baran	Ramganj Mandi
Normalized co-integrating coefficients (standard error in parentheses)	1.000000	0.000000	-0.937034 (0.05168)

Thus, it could be summarized from the above analysis that coriander prices in Kota, and Ramganj Mandi moved in tandem over the long run. However, in the long run, the directions of movement in coriander prices of KUMS, Kota showed a negative relationship with Ramganj Mandi. However, the direction of coriander prices in Kota was unaffected by changes in coriander prices in Baran.

Vector error correction model: The results of the short run equilibrium of the coriander price series were computed using VECM and are shown in Table 6. It was revealed from the table that KUMS, Kota and KUMS, Baran were reported short run equilibrium as indicated by the rapid speed of adjustment and significance level. In long run period, the coriander prices in Kota were influenced by one-month lag price of Baran, Ramganj Mandi and two-month lag price of its own. The coriander prices of Baran and Ramganj Mandi were influenced by one-month lag price of Ramganj Mandi and Kota, respectively. Sahu *et al.* (2019) reported in their study that coriander daily price series did not exhibit any short-run or long-run co-integration from October, 2015-April, 2017 in India.

Table 6. Results of vector error correction model for coriander prices in selected KUMS

Error correction	D(K)	D(BR)	D(RGM)
CointEq1	-0.262577	0.426847	0.025033
	(0.08241)	(0.10820)	(0.09610)
	[-3.18604]	[3.94484]	[0.26050]
D (K(-1))	-0.035207	-0.008802	0.332328
	(0.10170)	(0.13353)	(0.11858)
	[-0.34618]	[-0.06592]	[2.80246]
D (K(-2))	-0.222880	-0.137976	0.034886
	(0.10106)	(0.13268)	(0.11783)
	[-2.20547]	[-1.03991]	[0.29606]
D (BR(-1))	-0.190595	0.127256	0.029520
	(0.09112)	(0.11963)	(0.10625)
	[-2.09168]	[1.06371]	[0.27784]
D (BR(-2))	0.001506	0.002768	0.056312
	(0.07747)	(0.10171)	(0.09033)
	[0.01945]	[0.02722]	[0.62342]
D (RGM(-1))	0.505712	0.294201	-0.062304
	(0.10981)	(0.14418)	(0.12804)
	[4.60520]	[2.04057]	[-0.48659]
D (RGM(-2))	-0.084654	0.144975	-0.249553
	(0.11196)	(0.14699)	(0.13054)
	[-0.75611]	[0.98627]	[-1.91163]

Standard error in ( ) and t-statistic in [ ], K-Kota, BR-Baran and RGM-Ramganj Mandi

It could be inferred from the above discussion that coriander prices of Baran, and Ramganj Mandi were influenced by one-month lag coriander price of Ramganj Mandi and Kota. In case of Kota, the coriander prices were influenced by two-moth lag price of its own along with one-month lag price of coriander in Baran and Ramganj Mandi of Rajasthan.

Pair wise Granger-causality test analysis: A pair-wise Granger causality test was performed to determine whether there was co-integration between selected combinations of coriander price of two markets (Table 7). It was revealed from the table that *P-value* between coriander prices of Kota↔Baran, Ramganj Mandi↔Kota was less than 5 per cent in both directions. It indicated that coriander price showed bi-directional causality linkage of coriander price series on each other whereas for Ramganj Mandi→Baran it was showed one-way directional causal linkage in coriander prices. Sahu *et al.* (2019) reported in their study that turmeric, chilli and cumin were reported bi-directional impact rather causality. While in case of coriander price series, it was unidirectional causality linkage from future market to spot markets in India during October, 2015-April, 2017.

Table 7. Results of Pair wise Granger causality of coriander prices

Null hypothesis	Observations	*F-statistic*	*P-value*	Direction
BR does not Granger cause K	118	8.50769	0.0004	BR→K
K does not Granger cause BR		20.1753	3.E-08	K→BR
RGM does not Granger cause K	118	5.51275	0.0052	RGM→K
K does not Granger cause RGM		4.79790	0.0100	K→RGM
RGM does not Granger cause BR	118	32.1768	9.E-12	RGM→BR
BR does not Granger cause RGM		1.82600	0.1658	-

K-Kota, BR-Baran and RGM-Ramganj Mandi

Therefore, it could be summarized from the above analysis that there was bi-directional co-integration in the coriander prices of combinations of Baran↔Kota and Ramganj Mandi↔Kota. However, for the combination of Ramganj Mandi→Baran, it was unidirectional causality linkage in Rajasthan.

Fennel: The results of Augmented Dickey Fuller test for Niwai, Nagaur and Merta City the prices were integrated in the same order or are non-stationary at the level. The price series of fennel were found stationary in all selected KUMS namely Niwai, Nagaur and Merta City of Rajasthan at first difference. Furthermore, the coefficient of variable was shown to be negative. As a result, the integration order was found to be one. In their investigation, Ali & Gupta (2011) found that the spot and future market pricing series of pepper in India showed unit root at the level and were non-stationary at first difference.

Johansen's multiple co-integration analysis: Table 8 presents the results of long run co-integration analysis of fennel for selected markets in Rajasthan, *viz.,* Niwai, Nagaur, and Merta City.

The table showed that during the entire study period, the values of trace statistic and maximum Eigen of the unrestricted integration test revealed one co-integration equation at the 5 per cent level of significance. Therefore, selected markets had a long run association for the coriander prices in Rajasthan i.e., fennel prices in selected markets moved together over time. The directions of movement in fennel prices, on the other hand, were reported by coefficients of long run co-integration equation. In the KUMS, Niwai, the negative coefficient value (-0.216568) of fennel price is indicates that when the fennel price in KUMS, Niwai falls, the fennel price in KUMS, Nagaur will rise in the long-run. In the case of KUMS, Merta City, the coefficient value is ineffective (0.00000) which indicates that there is no positive or negative relationship with fennel price of KUMS, Nagaur. Sahu *et al.* (2019) found a long-run relationship between daily spot and future prices of chilli, turmeric, and cumin in India from October 2015 to April 2017.

Table 8. Results of Johansen's multiple co-integration analysis of fennel price

Hypothesized no. of CE(s)	Eigen value	Trace statistic	0.05 Critical value	*P-value***
None *	0.235838	45.97923	29.79707	0.0003
At most 1	0.073587	14.24009	15.49471	0.0766
At most 2 *	0.043279	5.220710	3.841466	0.0223

Trace test indicates 1 co-integrating equation @ 0.05 level
* denotes rejection of the hypothesis @ 0.05 level
**MacKinnon-Haug-Michelis (1999) *P-values*

	Coefficients of long run co-integration equation		
	Nagaur	Merta City	Niwai
Normalized co-integrating coefficients (standard error in parentheses)	1.000000	0.000000	-0.216568 (0.13558)

Thus, it could be summarized from the above analysis that in the long run, fennel prices in Nagaur, and Niwai moved together. However, in the long run, the directions of movement in fennel prices in Nagaur showed a negative relationship with that of Niwai. However, the direction of fennel prices in Nagaur was unaffected by changes in fennel prices in Merta City.

Vector error correction model: The results of the short run equilibrium of the fennel price were computed using VECM (Table 9). Niwai, and Merta City were reported to be in short run equilibrium, as indicated by the rapid rate of adjustment and significance level. In the long run, the fennel prices at Nagaur and Merta City were influenced by their own one-month lag price. Specifically, the fennel prices in Nagaur and Merta City were negatively correlated (-3.66117 and -3.11914, respectively). In the long-run, KUMS, Niwai fennel prices were unaffected. Sahu *et al.* (2019) reported in their study that there was no short-run or long-run co-integration in the coriander daily prices in India from October 2015 to April 2017.

Table 9. Results of vector error correction model for fennel price

Error correction	D(NI)	D(N)	D(M)
CointEq1	-0.328565	0.036619	0.369452
	(0.08794)	(0.05484)	(0.10952)
	[-3.73621]	[0.66769]	[3.37343]
D(NI(-1))	-0.037769	0.094754	-0.089997
	(0.09774)	(0.06096)	(0.12173)
	[-0.38641]	[1.55440]	[-0.73933]
D(N(-1))	-0.100808	-0.327706	0.173678
	(0.14352)	(0.08951)	(0.17874)
	[-0.70238]	[-3.66117]	[0.97168]
D(M(-1))	-0.097808	0.018583	-0.272845
	(0.07024)	(0.04381)	(0.08747)
	[-1.39248]	[0.42422]	[-3.11914]

Standard error in ( ) and t-statistic in [ ], Ni-Niwai, N-Nagaur and M-Merta City.

We can conclude that the fennel prices of Niwai, and Merta City were negatively associated with their one-month lag price. Short run equilibrium in fennel prices was reported in Niwai, and Merta City.

Pair wise Granger-causality test analysis: The results of the Pair-wise Granger causality test for the existence of co-integration between selected combinations of two-fennel price markets are given in Table 10. The table revealed that the P-value between fennel prices at Merta City↔Niwai was less than 5 per cent in both directions. It indicated that fennel prices had a bi-directional impact rather than a causal link between fennel price series. For fennel price, there was no co-integration between Nagaur and Niwai, nor between Nagaur and Merta City. Sahu *et al.* (2019) reported that turmeric, chilli, and cumin had a bi-directional impact rather than causality. In the case of the coriander price series, it was a unidirectional causality linkage from the futures market to the spot market in India from October 2015 to April 2017.

Table 10. Results of pair wise Granger causality of fennel prices

Null hypothesis	Observations	*F-statistic*	*P-value*	Direction
N does not Granger cause NI	119	0.29870	0.5858	-
NI does not Granger cause N		2.32370	0.1301	-
M does not Granger cause NI	119	8.11416	0.0052	M→NI
NI does not Granger cause M		13.8532	0.0003	NI→M
M does not Granger cause N	119	0.16514	0.6852	-
N does not Granger cause M		3.32552	0.0708	-

N-Niwai, N-Nagaur and M-Merta City.

As a result of the foregoing analysis, it can be concluded that bi-directional co-integration was found in the fennel price combinations of KUMS, Merta City ↔KUMS, Niwai in Rajasthan. Other combinations of selected fennel markets in Rajasthan did not show any directional co-integration.

Fenugreek. At first difference, the price series of fenugreek were found to be stationary in all selected KUMS, namely Kota, Bikaner, and Nokha. Furthermore, the coefficient of variable was found to be negative in all three forms of model. As a result, the integration order was observed to be one. Ali & Gupta (2011) found that spot and future market prices of pepper were unit root at the level and non-stationary at the first difference in India. The fenugreek price in Kota, Bikaner, and Nokha mandis were viable after first difference in all three models of the ADF test. The presence of non-stationary in fenugreek prices at the level demonstrates a co-integration between fenugreek prices in selected mandis. Thus, it is essential to employ a co-integration test to determine the long-run relationship between fenugreek prices in selected KUMS.

Johansen's multiple co-integration analysis: The presence of co-integration between fenugreek prices in KUMS was determined using Johansen's multiple co-integration test. Table 11 presents the results of long run co-integration analysis for selected KUMS, namely Kota, Bikaner, and Nokha. The values of trace statistic and maximum Eigen of the Johansen's multiple co-integration test revealed no co-integration equations at the 5 per cent level of significance.

As a result, selected markets did not have a long run association for fenugreek prices in Rajasthan, i.e. fenugreek prices in selected markets did not move together over time. Sahu *et al.* (2019) found a long-run relationship between daily spot and future prices of chilli, turmeric, and cumin in India from October 2015 to April 2017.

Table 11. Results of Johansen's multiple co-integration analysis of fenugreek price

Hypothesized no. of CE(s)	Eigen value	Trace statistic	0.05 Critical value	*P-value***
None	0.112874	22.24301	29.79707	0.2852
At most 1	0.067686	8.230077	15.49471	0.4411
At most 2	0.000257	0.030027	3.841466	0.8624

Trace test indicates no co-integrating equation @ 0.05 level
* denotes rejection of the hypothesis @ 0.05 level
**MacKinnon-Haug-Michelis (1999) *P-values*

	Coefficients of long run co-integration equation		
	Bikaner	Kota	Nokha
Normalized co-integrating coefficients (standard error in parentheses)	1.000000	1.891974 (0.57116)	-2.102415 (0.58461)

Thus, it could be summarized from the above analysis that fenugreek prices in Kota, Bikaner, and Nokha mandies did not move in tandem over long period of time. Therefore, it is not necessary to use VECM and the Granger-causality test.

Conclusions and policy implications

The results of the ADF test showed that original prices of cumin, coriander, fennel and fenugreek are integrated at the same order or non-stationary in selected Rajasthan markets over the study period. Cumin prices, on the other hand, were viable after the first difference in all three models of Augmented Dickey Fuller test. Throughout the study period, the trace statistic and maximum Eigen values of Johansen's multiple co-integration test revealed that three co-integration equations of prices of cumin, coriander and fennel in selected markets were significant at 5% level of significance and moved in lockstep over time.

The results of the VEC model revealed that cumin prices in Jodhpur, Nagaur and Merta City were influenced by one-month lag price of each other selected markets. The Pair-wise Granger-causality test reported that cumin prices combination of Merta City →Jodhpur demonstrated one-way co-integration. In case of coriander, the prices were moved together over time in the long run and influenced by one month lag price of each-other markets i.e. Kota, Baran and Ramganj Mandi. Kota and Baran markets showed short run equilibrium for coriander from 2011 to 2020. The Pair wise Granger-causality test indicated that coriander prices combinations in Baran↔Kota and Ramganj Mandi↔Kota had bi-directional causal linkage whereas combination of Ramganj Mandi→Baran showed one-way directional causal linkage.

Fennel prices in Rajasthan's selected markets moved together over time in the long run and associated with their own one month lag price.

Short run equilibrium in fennel prices was reported in Niwai and Merta City. Based on findings of the Pair wise Granger-causality test it could be concluded that fennel prices combination in Merta City↔Niwai had a bi-directional impact rather than unidirectional causal link. In case of fenugreek, the trace statistic and maximum Eigen values of Johansen's multiple co-integration test indicated that fenugreek prices in Kota, Bikaner, and Nokha mandies have not moved in lockstep for a long time.

It was indicated in findings that prices of selected seed spices were influenced by one month lag price of their own respective markets which could be due to dominance of a few large-scale traders in the cumin, fennel, and fenugreek crops, who owned the largest proportion of these spices in specific markets. Therefore, small producers should develop a cooperative trade organization to break the monopoly of major traders in the chosen KUMS of Rajasthan where financial assistance to the organization can play a key role in this regard.

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