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RESEARCH ARTICLE

Price Transmission and Signals of Cowpea Across Zones and Value Chain in Niger State of Nigeria

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ABSTRACT

This study investigated price transmission and signals of the three major urban cowpea markets and their respective adjunct rural market across the zones and value chain in Niger state of Nigeria using monthly time series data spanning from January 2003 to December 2016. The selected urban markets were Bida, Minna, and Kontagora, and their adjunct markets were Lafene, Zungeru, and Manigi, respectively. Model build on the assumption of linear and symmetric price transmission was used to analyze the data. The stationarity tests showed that the price series of all the variables were integrated of order one. The cointegration test results of the markets both at horizontal and vertical integrated levels proved that despite that, these markets were spatially separated geographically; they were well connected in terms of price transmission across them. It was observed that price changes are temporary and would converge to equilibrium within a given time span. However, Bida market was found to me more pricing and operational efficiency when compared to its counterparts because of its close proximity to the largest terminal markets for cowpea in the country, i.e., Lagos state and other states in the southwest of Nigeria. Furthermore, the price signals across the zones and value chain will be well transmitted, indicating that price changes in one zone are consistently related to the price changes in other zones and are able to influence the prices in other zones. However, the direction and intensity of price changes may be affected by the dynamic linkages between the demand and supply of cowpea. A proper focus on domestic supply management along with international trade coupled with strong market surveillance and intelligence efforts would help control escalating prices and also help in minimizing the distortions widening the gap between the wholesale and retail prices of cowpea.

Key words: Across zones, cowpea markets, Nigeria, Price transmission, signals, value chain

INTRODUCTION

The rapid development in agricultural research and the introduction of technological innovations, namely, high-yielding varieties, improved agricultural implements, fertilizers, and pesticides, have brought about a breakthrough in Nigeria agriculture. This development in agriculture, popularly known as the green revolutions, has given rise to new problems in agricultural marketing. It is essential to maintain the tempo of these revolutions. The farmers should be assured of a fair price for their produce, failing which they may lose the incentive to increase agricultural production. A fair price for the product may be assured when there is an orderly marketing system in the country. Market intelligence being an important adjunct of orderly marketing has emerged as another problem. With the increased marketed surplus and opening up of the trade, the importance

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of market intelligence has increased. Farmers market their produce in the villages and nearby assembling centers out of their ignorance of the prevailing price in the nearby primary wholesale, secondary wholesale, and terminal markets. Traders take full advantage of the ignorance of the farmer because they have full knowledge of the prices prevailing in other markets, thus, placing these traders in a superior bargaining position. However, an orderly marketing system can be created only when the problems, which have emerged, are effectively tackled. There is an urgent need in the present context for tackling the emerging problems of agricultural marketing more resolutely and efficiently than before. The improvement in the domestic marketing system has assumed special significance with the launch of green alternatives in 2016 and opening up of the external trade regime.[1,2]

RESEARCH METHODOLOGY

The study made use of monthly time series data spanning from January 2003 to December 2016 of one major urban cowpea market with its respective one major adjunct rural market in each of the three zones cutting across the state. The chosen urban adjunct rural (urban-rural) markets were Bida-Lafene, Minna–Zungeru, and Kontagora–Manigi. The analytical tools used are given below:

1. Augmented Dickey-Fuller (ADF) test

The ADF is the test for the unit root in a time series sample (Blay *et al*., 2015). The autoregressive formulation of the ADF test with a trend term is given below:

$$\Delta p_t = \alpha + p_{t-1} + \sum_{j=2}^{it} \beta i \Delta p_{it-j+t} + \varepsilon \quad (1)$$

Where, p_{it} is the price in market i at the time t, Δpit (p_{it}–p_{t-1}), and α is the intercept or trend term.

2. Johansen's cointegration test

The Johansen procedure is a multivariate generalization of the Dickey-Fuller test, and the formulation is as follows (Johansen, 1988):

$$p_t = A_1 p_{t-1} + \varepsilon_t \quad (2)$$

So that

$$\Delta p_t = A_1 p_{t-1} - p_{t-1} + \varepsilon_t \quad (3)$$

$$p_t = (A_1 - I) p_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta p_t = \prod p_{t-1} + \varepsilon_t \quad (5)$$

Where, p_t and ε_t are (n × 1) vectors; A_t is an (n × n) matrix of parameters; I is an (n × n) identity matrix, and $\prod$ is the (A_1-1) matrix.[3]

Using the estimates of the characteristic roots, the tests for the number of characteristic roots that are insignificantly different from unity were conducted using the following statistics:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} ln(1-\lambda_i) \quad (6)$$

$$\lambda_{max} = -T\, ln(1-\lambda_i + 1) \quad (7)$$

Where, λ_i denotes the estimated values of the characteristic roots (Eigenvalues) obtained from the estimated $\prod$ matrix, and T is the number of usable observations.

3. Granger causality test

Granger (1969) causality test was used to determine the order and direction of short-term and long-term equilibrium relationships. Whether market p_1 Granger causes market p_2 or vice-versa was checked using the following model:

$$p_t = c + \sum_{i=1}^{n} (\phi p_{1t-i} + \delta_i p_{2t-i}) + \varepsilon_i \quad (8)$$

A simple test of the joint significance of δ_i was used to check the Granger causality, i.e.

H_0: $\delta_1 = \delta_2 = \ldots\ldots \delta_n = 0$.

4. Vector error correction model (VECM)

The VECM explains the difference in y_t and y_{t-1} (i.e. Δy_t) and it is shown below (Sadiq *et al*., 2016a; Sadiq *et al*., 2016b):

$$\Delta y_t = a + \mu(y_{t-1} - \beta x_{t-1}) + \sum_{i=0}^{i=t} \delta_i \Delta x_{t-1} + \sum_{i=1}^{i=t} \gamma_i \Delta \gamma_{t-1} \quad (9)$$

It includes the lagged differences in both x and y, which have a more immediate impact on the value of Δy_t.

5. Impulse response functions

The GIRF in the case of an arbitrary current shock, δ, and history, ω_{t-1} is specified below (Rahman and Shahbaz, 2013; Beag and Singla, 2014):

$$GIRF_Y(h, \delta, \omega_{t-1}) = E[Y_t + h|\delta, \omega_{t-1}] - E[y_{t-1}|\omega_{t-1}] \quad (10)$$

6. Forecasting accuracy

For measuring the accuracy in fitted time series model, mean absolute prediction error (MAPE), relative mean square prediction error (RMSPE), and relative MAPE (RMAPE) (Paul, 2014) and R^2 were computed using the following formulae:

$$MAPE = 1/T \sum \{A_t - F_t\} \quad (11)$$

$$RMPSE = 1/T \sum \{(A_t - F_t)^2/A_t\} \quad (12)$$

$$RMAPE = 1/T \sum \{(A_t - F_t)/A_t\} \times 100 \quad (13)$$

$$R^2 = \frac{1 - \sum_{i=1}^{n}(A_{ti} - F_{ti})}{\sum_{i=1}^{n} A_{ti}} \quad (14)$$

Where, R^2 = Coefficient of multiple determination, A_t = Actual value; F_t = Future value, and T = time period(s)

RESULTS AND DISCUSSION

Lag length selection criteria

Too many lags could increase the error in the forecasts; too few could leave out relevant information. Experience, knowledge, and theory are usually the best way to determine the number of lags needed. The following information criteria most widely used, namely, Akaike information criterion, Schwarz Bayesian information criterion, and Hannan-Quinn criterion were used to select the optimal truncation lag length to ensure that the errors are white noise in ADF. Based on democratic principle, the test results, as shown in Table 1, reveal that the optimum lag length appropriate for the specified variables is lag one because all the information criteria chose lag one as indicated by the asterisks of the information criteria. This means that in generating ADF and all the subsequent models, the optimum lag length of time series should be 1 to obtain more interpretable parsimonious results and avoid biases of time series due to their sensitive nature toward lag length.[4-6]

Unit root test

The stationarity of the price indices was tested before establishing the causal relationship between different markets in the state. The ADF test was employed, and the presence of unit root was checked under different scenarios of the equation, such as with intercept, with intercept and trend, and none [Table 2]. ADF-GLS test, which provides an alternate method for correcting serial correlation and heteroscedasticity, was used to validate the results.[7] The ADF results of the unit root test did not reject the null hypothesis of the presence of unit root for all the price series when the variables were considered at the level, as indicated by the t-statistic values which were greater than the t-critical values at 5% probability level. At the succeeding level, the first differenced series of all the price variables were found to be stationary, as indicated by the t-statistic values which were lower than the t-critical values at 5% probability levels. Furthermore, the ADF-GLS results of unit root test show that all the price series variables were non-stationary at level as indicated by t-statistic values which were higher than t-critical at 5% probability level; but at first difference, they became stationary as shown by t-statistic values which were lower than t-critical at 5% probability level, thus, validating robustness of the earlier results generated using ADF-test. Since the variables were non-stationary at levels, any attempts to use them will lead to spurious/nonsense regression, and this is not ideal for policymaking and cannot be used for long run prediction. With the evidence that the price series were non-stationary and integrated of order one, the test for cointegration among the selected cowpea markets in the state using Johansen's maximum likelihood approach was applied.

Table 1: Lag selection criteria

Lag(s)	AIC	BIC	HQC
1	54.26*	55.07	54.59*
2	54.52	56.03	55.13
3	54.88	57.09	55.77
4	54.58	57.48	5.76
5	54.77	58.38	56.24
6	54.87	59.18	56.62
7	54.45	59.45	56.48
8	54.64	60.33	56.95
9	54.80	61.19	57.39
10	55.00	62.09	57.88

AIC: Akaike information criterion, BIC: Bayesian information criterion, HQC: Hannan–Quinn information criterion

Multivariate cointegration tests for horizontal integrated rural and urban markets

The results of the horizontal cointegration tests for the rural and urban markets are presented in Table 3. Using the identified optimal lag length, i.e., lag one, the Johansen cointegration test was undertaken, and the cointegrating equation was identified using the trace statistic and max Eigenvalue test. For rural markets, the cointegration tests showed only two cointegrating equations, as evidenced by the trace and maximum Eigenvalues which were below their corresponding critical values at 5% significance level, indicating that there is one stochastic trend present in the system. Furthermore, the cointegration tests showed only two cointegration equations for the selected urban markets for cowpea in the state, as indicated by the trace and maximum Eigenvalues which were below their corresponding critical values at 5% significance level indicating that they shared the same stochastic trend in the system. In summary, it means that across the rural and urban markets of cowpea in the different region of the state, there was two cointegrating relationship. Since both tests across the rural and urban markets for cowpea confirmed that all the three selected markets under each scenario had two cointegrating vectors out of three cointegrating equations, it implies that in each scenario, the markets were well integrated and price signals were transmitted from one market to the other to ensure efficiency. The higher the number of cointegrating vectors the stronger the relationship between the variables in the system. Thus, Johnson cointegration test has shown that even though the cowpea markets under each case in the state are geographically isolated and spatially segmented, they were well-connected in terms of cowpea prices, demonstrating that the markets under each scenario had long-run price linkage across them. Since these markets in each scenario, i.e., producer and wholesale markets move together, in the long-run, they are likely to establish long-run equilibrium.

Bivariate horizontal cointegration tests for rural and urban markets

The results of a horizontal pair-wise cointegration that was also performed across the rural and urban markets are given in Table 4. The decomposition analysis across the rural and urban markets is as follows: For the rural markets, the test showed that each market pair, namely, Lefane-Zungeru, Lefane-Manigi, and Zungeru-Manigi had one cointegrating equation, meaning that these market pairs were cointegrated and there exists long-run price association between them. For the urban markets, the test showed that each market pair, namely, Bida-Minna, Bida-Kontagora, and Minna-Kontagora had one cointegrating equation,

Table 2: Unit roots test

Market	Stage	ADF		ADF-GLS		Remarks
		T-stat.	*P*<0.05	T-stat.	T-critical (5%)	
Bida	Level	−0.394	0.9079	−1.506	−2.93	Non-stationary
	1st difference	−12.02**	9.04E-026	−16.83**	−2.93	Stationary
Lefane	Level	−0.525	0.884	−1.422	−2.93	Non-stationary
	1st difference	−10.89**	4.46E-022	−13.06**	−2.93	Stationary
Minna	Level	−1.643	0.095	−4.96	−2.93	Non-stationary
	1st difference	−15.37**	5.66E-033	−21.40**	−2.93	Stationary
Zungeru	Level	−1.379	0.594	−1.007	−2.93	Non-stationary
	1st difference	−13.08**	3.25E-029	−17.46**	−2.93	Stationary
Kontagora	Level	−1.173	0.689	−1.95	−2.93	Non-stationary
	1st difference	−10.92**	3.60E-022	−13.13**	−2.93	Stationary
Manigi	Level	−0.289	0.924	−1.436	−2.93	Non-stationary
	1st difference	−11.83**	3.73E-025	−15.35**	−2.93	Stationary

**indicate that unit root at the level or at first difference was rejected at 5% significance, ADF-GLS: Augmented Dickey-Fuller

Table 3: Multivariate horizontal cointegration results for rural and urban markets

H_0	H_1	Eigen value	Trace test	*P*-value	Lmax test	*P*-value
			Rural market			
r=0	r≥1	0.397	152.98**	0.0000	84.59**	0.0000
r≤1	r≥2	0.336	68.39**	0.0000	68.24**	0.0000
r≤2	r=3	0.00087	0.145	0.7031	0.145	0.7031
			Urban market			
r=0	r≥1	0.476	178.90**	0.0000	107.94**	0.0000
r≤1	r≥2	0.342	70.960**	0.0000	69.906**	0.0000
r≤2	r=3	0.0063	1.054**	0.3045	1.0544	0.0000

**denotes rejection of the null hypothesis at 5% level of significance indicating that these market pairs were cointegrated, and there exists long-run price movement between them. However, a situation of no cointegration between market pair across the rural and urban market was not observed, thus, indicating that in pair-wise the power of these markets was not concentrated in the hand of few; there was an adequate flow of market information and proper marketing infrastructure.

Bivariate cointegration results of vertical integrated markets (urban-rural markets)

In addition to horizontal cointegration, the vertical cointegration between the rural and urban prices of cowpea for different markets in the state was also investigated using Johansen's cointegration test [Table 5]. The tests showed that each market pair, namely, Bida-Lefane, Minna-Zungeru, and Kontagora-Manigi had one cointegrating relationship, indicating that these market pairs were vertically integrated markets that were cointegrated. Therefore, it can be inferred that despite been spatially separated, there existed price transmission between these market pairs in the long-run, i.e., they had long-run price association or comove together in the long run, and thus, likely to establish equilibrium in the long-run.

Multivariate VECM of horizontal integrated rural markets

The results of the VECM estimates for the multivariate horizontal cointegrated prices of selected rural markets in the different regions of the state are presented in Table 6. The coefficient of the error correction term (ECT) for Lafene and Manigi markets was significant for all three combinations, confirming the presence of partial horizontal cointegration. The coefficient of the ECT was negative and significant in the case of the Lafene market; and, positive and significant for the Manigi market. This implies that the prices of cowpea in these markets were stable in the long-run and any

Table 4: Bivariate horizontal cointegration results for rural and urban markets

Market pair	H_0	H_1	Trace test	*P*-value	Lmax test	*P*-value	CE
Rural market							
Lefane–Zungeru	r=0	r≥1	69.05**	0.0000	68.32**	0.0000	1CE
	r≤1	r≥2	0.730	0.3928	0.730	0.3929	
Lefane–Manigi	r=0	r≥1	84.57**	0.0000	84.41**	0.0000	1CE
	r≤1	r≥2	0.166	0.6834	0.166	0.6834	
Zungeru–Manigi	r=0	r≥1	72.179**	0.0000	71.858**	0.0000	1CE
	r≤1	r≥2	0.321	0.5710	0.321	0.5710	
Urban market							
Bida–Minna	r=0	r≥1	108.58**	0.0000	107.66**	0.0000	1CE
	r≤1	r≥2	0.9160	0.3385	0.9160	0.3385	
Bida–Kontagora	r=0	r≥1	72.487**	0.0000	71.318**	0.0000	1CE
	r≤1	r≥2	1.169	0.2796	1.169	0.2797	
Minna–Kontagora	r=0	r≥1	105.04**	0.0000	102.78**	0.0000	1CE
	r≤1	r≥2	2.254	0.1332	2.254	0.1332	

**denotes rejection of the null hypothesis at 5% level of significance, CE: Cointegration equation

Table 5: Bivariate cointegration results of vertical integrated markets

Market pair	H_0	H_1	Trace test	*P*-value	Lmax test	*P*-value	CE
Bida–Lafene	r=0	r≥1	123.08**	0.0000	122.61**	0.0000	1CE
	r≤1	r≥2	0.4678	0.4641	0.4675	0.4941	
Minna–Zungeru	r=0	r≥1	106.40**	0.0000	105.10**	0.0000	1CE
	r≤1	r≥2	1.299	0.2544	1.299	0.2544	
Kontagora-Manigi	r=0	r≥1	62.098**	0.0000	61.247**	0.0000	1CE
	r≤1	r≥2	0.8509	0.3563	0.8509	0.3563	

**denotes rejection of the null hypothesis at 5% level of significance, CE: Cointegration equation deviation in these due to external shocks that occur in the short-run, were well adjusted. However, the ECT of prices in Zungeru market was positive but non-significant; indicating that this market did not correct its previous period error if there is any shock originating from any of the short-run equilibrium. This outcome is not surprising because the quantity of arrival in this market is low when compared to the quantity of arrivals in the two selected markets. The error correct term coefficients for Lafene and Manigi market prices were −0.465 and 0.346, indicating how fast the dependent variables absorb and adjust themselves for the previous period disequilibrium errors. In other words, the VEC coefficient measures the ability of Lafene and Manigi market prices to incorporate shocks or speculations in the prices. In this case, Lafene and Manigi markets absorbed 45.6% and 34.6%, respectively, to move toward equilibrium in the prices. The information flow was more pronounced in the Lafene market as evident from the magnitude of the VEC coefficient, and also because it is a pure satellite of Bida market. A clear unidirectional lead-lag relationship can be established that flows from Lafene market to Zungeru-Manigi markets.

Multivariate VECM for horizontal urban markets

The presence of cointegration indicates the existence of long-run equilibrium among the cointegrated variables. The long-run and short-run dynamics of the cointegrated equation were modeled through the VECM [Table 7]. The estimates of VECM show that only prices of Bida market speed of adjustment coefficient was negative and significant, implying that prices in this market tend to converge in the long-run; while the speed of adjustment coefficients for Minna and Kontagora market prices were positive and significant, indicating that they diverge from the equilibrium. For Bida market the speed of adjustment coefficient was −0.464, indicating that 46.4% of divergence from the long-run equilibrium was been corrected each month, i.e., it will take about 16 days to re-establish equilibrium if there is distortion from any of the short-run equilibrium. In the case of Minna and Kontagora market prices, the speed of adjustment coefficients were 0.399 and 0.30, respectively, implying that 39.9% and 30% of divergence from the long-run equilibrium were been corrected each month, i.e., it will take about 18 and 21 days to re-establish equilibrium for Minna and Kontagora market prices, respectively, if there is distortion from any of the short-run equilibrium. The prices of cowpea in Bida market are above the equilibrium and quickly fall back toward the price level of Minna-Kontagora markets, while that of Minna and Kontagora markets were below the equilibrium and quickly adjusts toward the price levels of Bida-Kontagora markets, and Bida-Minna markets, respectively. The process of adjustment, however, was relatively faster between the markets of Bida to Minna-Kontagora and Minna to Bida-Kontagora. This might be due to lesser transfer and transaction costs in these markets due to proximity and better infrastructure. In addition, the Bida market gets its product cleared off immediately because of its proximity to largest consuming markets-south Western part of Nigeria, while Minna market is situated in the metropolitan area which enhances its efficiency. Furthermore, based on the sign of the

Table 6: Multivariate VECM of horizontal integrated rural markets

Variable	D(Lefane)	D(Zungeru)	D(Manigi)
ECT_{t-1}	−0.465	0.788	0.346
	(0.0864)	(0.593)	(0.097)
	[−5.382]***	[1.329]^{NS}	[3.584]***
ECT_{t-2}	0.0136	−0.6199	0.0103
	(0.0124)	(0.085)	(0.0139)
	[1.101]^{NS}	[−7.296]***	[0.7402]^{NS}
Constant	2.678 (2.014)^{NS}	−80.24 (13.82)***	2.608 (2.252)^{NS}

***,**,* implies significance at 1%, 5%, and 10%, respectively. NS: Non-significant, (); [ ] implies standard error and t-statistic, VECM: Vector error correction model, ECT: Error correction term

Table 7: Multivariate VECM of horizontal integrated urban markets

Variable	D(Bida)	D(Minna)	D(Kontagora)
ECT_{t-1}	−0.464	0.3993	0.2996
	(0.0834)	(0.2061)	(0.0877)
	[−5.563]***	[1.937]*	[3.416]***
ECT_{t-2}	0.0600	−0.9027	0.0398
	(0.0312)	(0.0771)	(0.0328)
	[1.925]*	[−11.71]***	[1.212]^{NS}
Constant	−0.4796 (1.528)^{NS}	13.05 (3.776)***	0.837 (1.606)^{NS}

***,**,* implies significance at 1%, 5%, and 10%, respectively. NS: Non-significant, (); [ ] implies standard error and t-statistic, VECM: Vector error correction model, ECT: Error correction term

ECT, Bida market is efficient in pricing because of its market size-large quantity of arrivals; in terms of establishment it is an older market; the market power is concentrated in the hand of many traders, and the traders have adequate access to information. In the case of Minna and Kontagora, despite been an old establishment, large markets, and having adequate access to market information, the major factor hindering its efficiency is that the power of these markets is concentrated in the hand of few traders.

Bivariate VECM for horizontal integrated rural markets

The acceptance of cointegration between two variables indicates that there they are likely to establish long-run equilibrium between them, and this means that VECM is applicable, which combines the long-run relationship with the short-run dynamics of the model. The bivariate VECMs of cowpea prices for the horizontal rural markets in different regions in the state are shown in Table 8. A perusal of the results shows that the prices of market pair, namely, Lefane-Zungeru did not establish long-run equilibrium, as evidenced by the ECT coefficient which was not significant, but in the reverse situation, the prices of the market pair: Zungeru-Lafene established long-run equilibrium as evidence by the ECT which is significant. Furthermore, Lefane-Manigi market pair established long-run equilibrium, likewise Manigi-Lefane market pair established long-run equilibrium as evidence by the ECT coefficients which were significant. For Zungeru-Manigi market pair there exist long-run equilibrium, likewise Manigi-Zungeru markets there exist long-run equilibrium as indicated by the ECT coefficients which were significant. In other words, for Lefane-Zungeru markets there was no long-run causality running from Zungeru market to Lefane market, but there was long-run causality running from Lefane market to Zungeru market indicating that approximately 235% of long run disequilibrium is corrected each month by changes in the prices of cowpea at Lefane market. For Lefane-Manigi markets, there was long-run causality running from Manigi market to Lefane market indicating that about 41.5% of long run disequilibrium is corrected each month by changes in the prices of cowpea at Manigi market. Likewise a long-run causality running from Lefane market to Manigi market indicating that approximately 38.4% of long run disequilibrium is corrected each month by changes in the prices of cowpea at Lefane market. And for Zungeru-Manigi markets, there was long-run causality running from Manigi market to Zungeru market indicating that approximately 56% of long run disequilibrium is corrected each month by changes in the prices of cowpea at Manigi market. Likewise a long-run causality running from Zungeru market to Manigi market indicating that approximately 3.6% of long-run disequilibrium is corrected each month by changes in the prices of cowpea at Zungeru market.

Bivariate VECM for horizontal urban markets

The acceptance of cointegration between two series implies that there exists a long-run relationship between them, and this means that VECM is

Table 8: Bivariate VECM for horizontal integrated rural markets

Market pairs	ECT_{t-1}		Constant	
	1st variable	2nd variable	1st variable	2nd variable
Lefane–Zungeru	−0.0607	2.3539	2.9903	−79.245
	(0.0518)	(0.3357)	(2.1951)	(14.213)
	[−1.170]NS	[7.013]***	[1.362]NS	[7.013]***
Lefane–Manigi	−0.4149	0.3837	0.8202	1.1987
	(0.0735)	(0.0820)	(1.0901)	(1.2164)
	[−5.642]***	[4.676]***	[0.7524]NS	[0.9854]NS
Zungeru–Manigi	−0.5602	0.0364	−72.482	6.1944
	(0.0724)	(0.0724)	(12.472)	(2.0989)
	[−7.734]***	[−7.734]***	[−5.811]***	[2.951]***

***,**,* implies significance at 1%, 5%, and 10% respectively. NS: Non-significant, (); [ ] implies standard error and t-statistic, VECM: Vector error correction model, ECT: Error correction term applicable, which combines the long-run relationship with the short-run dynamics of the model.

Therefore, after confirming the cointegration in prices of cowpea across different urban and rural markets in the state, the ECT were measured and are reported in Table 9. In the case of urban markets, all the pair-wise market VECM established equilibrium, as evidenced by the ECTss which were significant at various probability levels. The ECT coefficients for Bida-Minna markets were −0.061 and 0.672, respectively, indicating that prices of cowpea in Bida market is too high, and it quickly falls back toward the price level of Minna market at the speed of 6.1% which is very low, while the prices at Minna market quickly adjust back toward the price level of Bida market at the same time that the Bida market prices are adjusting. For Bida-Kontagora markets, the ECT coefficients are −0.44 and 0.32, respectively, meaning that prices of cowpea in Bida market is too high, and it quickly falls back toward the price level of Kontagora market at the speed of 44% which is high, while the prices at Kontagora market quickly adjust back toward the price level of Bida market at the same time that the Bida market prices are adjusting. Furthermore, in the case of cowpea prices for Minna-Kontagora markets, the ECT coefficients are −0.88 and 0.056, respectively, implying that the prices of cowpea in Minna market are too high and it quickly falls back toward the price level of Kontagora market at the speed of 88% which is very high, while the prices at Kontagora market quickly adjust back toward the price level of Minna market at the same time that the Minna market prices are adjusting. The time frame at which cowpea prices at Bida market re-established equilibrium with Minna and Kontagora was 28 and 17 days, respectively; time frame at which prices at Minna market re-established equilibrium with Bida and Kontagora markets was 10 and 4 days, respectively, and the time frame at which Kontagora market re-established equilibrium with Bida and Minna markets was 20 and 28 days, respectively. Based on these findings it can be inferred that Bida market is more established than Minna and Kontagora markets, and in turn, Minna market is more established than Kontagora market. Furthermore, a clear unidirectional lead lag-relationship can be established that flows from Bida market to Minna market and Bida market to Kontagora market. This justified the earlier results which proved that Bida market is more technical and pricing efficient when compared to the other two selected markets in different regions of the state.

Bivariate VECM for vertical integrated markets

The results of bivariate VECMs for vertically integrated cowpea markets in the state are presented in Table 10. A cursory review shows that the ECT coefficients for Bida-Lefane vertical market integration were −0.72 and 0.30, respectively, and all significant, indicating that the prices of cowpea at Bida market (urban) converge toward its long-run equilibrium at a high-fast speed while the prices of cowpea at Lefane market (rural) converge toward its long-run equilibrium at a low speed. The ECT coefficients for Minna-Zungeru vertical market integration were −0.725 and 0.983, respectively, and all significant, indicating that the prices of cowpea at Minna market (urban) converge toward

Table 9: Bivariate VECM for horizontal integrated urban markets

Market pairs	ECT_{t-1}		Constant	
	1st variable	2nd variable	1st variable	2nd variable
Bida-Minna	−0.0610	0.6719	0.0482	13.312
	(0.0250)	(0.0579)	(1.6319)	(3.775)
	[−2.435]**	[11.60]***	[0.0295]NS	[3.526]***
Bida-Kontagora	−0.4402	0.3156	0.3574	1.3343
	(0.0832)	(0.0869)	(1.4817)	(1.5479)
	[−5.293]***	[3.633]***	[0.2412]NS	[0.8620]NS
Minna-Kontagora	−0.8816	0.0560	12.947	−0.0028
	(0.0769)	(0.0335)	(3.787)	(1.6502)
	[−11.47]***	[1.673]*	[3.418]***	[−0.0017]NS

***,**,* implies significance at 1%, 5%, and 10%, respectively. NS: Non-significant, (); [ ] implies standard error and t-statistic, VECM: Vector error correction model, ECT: Error correction term its long-run equilibrium at a high-fast speed while the prices of cowpea at market Zungeru (rural) converge toward its long-run equilibrium at a very high-fast speed. Furthermore, The ECT coefficients for Kontagora-Manigi vertical market integration were −0.491 and 0.238, respectively, and were all significant, indicating that the prices of cowpea at Kontagora market (urban) converge toward its long-run equilibrium at a moderately-fast speed while the prices of cowpea at Manigi market (rural) converge toward its long-run equilibrium at a very low speed. Furthermore, on the basis of sign of the ECT coefficient, it was observed that the prices of cowpea in all the selected urban (supply) markets were high and above the equilibrium, while that of all the selected rural (producing) markets were low and below the equilibrium, thus, signifying that all the urban markets were more efficient than the rural markets which are attributed to adequate information, proper infrastructure and are well-established institution considering the years existence of these markets. Based on these findings, a clear unidirectional lead-lag relationship can be established that flows from urban (supply) markets to rural (producing) markets, i.e., the prices of cowpea in urban (supply) markets had lead effects on prices of cowpea in their respective annexed rural (producing) markets.

Pair-wise granger causality tests of horizontal integrated rural markets

Having established the existence of cointegration between the producer prices of rural markets, the Granger causality test was used to identify the causal variable between them. The results of pair-wise Granger causality test in Table 11 showed that there was a bidirectional influence of prices between Lefane and Manigi markets, implying that both markets exhibit feed forward and feed backward mechanism in price formation between them. The results of pair-wise granger causality for Zungeru-Manigi market pair show that the Zungeru market exhibited strong exogeneity with Manigi market (unidirectional causality), i.e., Zungeru market had a causal effect on price formation in the Manigi market, while prices in the Manigi market in-turn did not exert influence on price formation in the Zungeru market. Thus, the price of cowpea in the Zungeru market seemed to be exogenous and was determined

Table 10: Bivariate VECM for vertical integrated markets (urban-rural)

Market pairs	ECT_{t-1}		Constant	
	1st variable	2nd variable	1st variable	2nd variable
Bida–Lefane	−0.7287	0.3001	5.4619	−0.9404
	(0.1092)	(0.0889)	(1.5541)	(1.2651)
	[−6.675]***	[3.377]***	[3.515]***	[−0.7433]NS
Minna–Zungeru	−0.7248	0.9827	36.297	−43.210
	(0.0636)	(0.1316)	(4.7865)	(9.9134)
	[−11.40]***	[7.465]***	[7.583]***	[−4.359]***
Kontagora–Manigi	−0.4914	0.2378	4.715	−0.7259
	(0.1193)	(0.0996)	(1.801)	(1.5047)
	[−4.120]***	[2.387]**	[2.618]***	[−0.4824]NS

***,**,* implies significance at 1%, 5%, and 10% respectively. NS: Non-significant, (); [ ] implies standard error and t-statistic, VECM: Vector error correction model, ECT: Error correction term

Table 11: Pair-wise granger causality tests of horizontal integrated rural markets

Null hypothesis	χ^2	Prob. χ^2	Granger cause	Direction
Lefane→Zungeru	1.2141	0.271NS	No	None
Zungeru←Lefane	1.7576	0.185NS	No	
Lefane→Manigi	31.305	0.000***	Yes	Bidirectional
Manigi←Lefane	12.875	0.000***	Yes	
Zungeru→Manigi	9.9369	0.002***	Yes	Unidirectional
Manigi←Zungeru	0.54307	0.461NS	No	

***,**,* denotes rejection of the H_0 at 1%, 5%, and 10% level of significance, respectively. NS: Non-significant outside the system perhaps by quality, bad news, and to some extent by export demand. Furthermore, it was observed that Lefane-Zungeru market pair had no causal effects on each other, i.e. neither the former granger cause price formation in the latter nor the latter granger cause price formation in the former. Therefore, based on these outcomes it can be inferred that there was super exogeneity between the prices of cowpea in Lefane-Zungeru market pair, strong exogeneity between prices of cowpea in Zungeru-Manigi market pair, and strong endogeneity between Lefane-Manigi market pair. In addition, since Lefane-Manigi markets were satellite of each other in price formation, and Manigi market again is a pure satellite of Zungeru market in price formation, while Zungeru market is not a satellite to any of the selected rural markets, thus, it implies that prices of cowpea in Zungeru market has direct and indirect influence on the rest of the selected rural markets in different regions of the state.

Granger causality tests of horizontal integrated urban markets

After establishing cointegration among different urban cowpea markets, granger causality was also estimated between the selected pairs of urban cowpea markets in the state. The granger causality shows the direction of price formation between two markets and related spatial arbitrage, i.e., physical movement of the commodity to adjust the price difference. The results of Granger causality tests presented in Table 12 reveals that all the two Chi-square for the causality tests of supply prices in Bida market on other markets were statistically significant. Thus, the null hypothesis of no Granger causality was rejected in each case for Bida market. Besides, Minna and Kontagora markets in each had one Chi-square statistically significant on other market prices. According to the granger causality test, there were bidirectional causalities between the Bida-Minna and Bida-Kontagora supply markets, implying that the former market in each pair granger causes the supply price formation in the latter market which in turn provides the feedback to the former market as well. The presence of the bi-directional Granger Causality between these urban (supply) markets indicates that there is a perfect price transmission mechanism between these market pairs.

Further, market pair, namely, Minna-Kontagora, has no direct causality between them, indicating that neither Minna market granger causes the price formation in Kontagora market, nor the Kontagora market granger causes the price formation in Minna market. In other words, there is no long-run price association between these market pairs. Therefore, it can be inferred that supply prices in Bida market have lead influence/effect on the other selected urban markets, thus, justifying the earlier finding which proved Bida market to be more developed in terms of establishment; have higher quantity of arrival which get cleared within shortest possible due to its proximity to the largest terminal and export market (Southwest of Nigeria); the market power concentration is in the hand of many traders, and there is adequate flow of information which minimizes arbitrage in the market. In addition, the result implies a perfectly competitive market situation and strong endogeneity between supply prices of Bida markets and the supply prices of other selected urban markets in other regions in the state.

Pair-wise granger causality tests of vertical integrated markets (urban-rural)

The way of interaction, as resulted from pair-wise Granger causality testing, is presented in Table 13.

Table 12: Pair-wise Granger causality tests of horizontal integrated urban markets

Null hypothesis	χ^2	Prob. χ^2	Granger cause	Direction
Bida→Minna	3.6406	0.056*	Yes	Bidirectional
Bida←Minna	3.558	0.059*	Yes	
Bida→Kontagora	25.594	0.000***	Yes	Bidirectional
Bida←Kontagora	10.543	0.001***	Yes	
Minna→Kontagora	1.8991	0.168^{NS}	No	None
Minna→Kontagora	1.4033	0.236^{NS}	No	

***,**,* denotes rejection of the H_0 at 1%, 5%, and 10% level of significance, respectively. NS: Non-significant

Table 13: Pair-wise Granger causality tests of vertically integrated markets

Null hypothesis	χ^2	Prob. χ^2	Granger cause	Direction
Bida→Lefane	44.172	0.000***	Yes	Bidirectional
Bida←Lefane	11.171	0.001***	Yes	
Minna→Zungeru	81.781	0.000***	Yes	Bidirectional
Minna←Zungeru	51.398	0.000***	Yes	
Kontagora→Manigi	15.224	0.000***	Yes	Bidirectional
Kontagora←Manigi	5.9906	0.014**	Yes	

***,**,* denotes rejection of the H_0 at 1%, 5%, and 10% level of significance, respectively. NS: Non-significant

It clearly indicates how vertically integrated markets interact among themselves regarding urban and rural price information flow for cowpea in Niger state. A cursory review of the results shows that all the vertical integrated markets considered for this study exhibited bidirectional causality, meaning that for each vertically integrated market, the urban market granger cause price formation in the rural market, and the rural market in-turn granger cause price formation in the urban market. Therefore, these markets under vertical integration are a satellite to each other in the formation of price, i.e., none has a lead influence on price formation of its pair. In addendum, there existed perfect flow of price information between these market pairs under vertical integration. This leads to the conclusion that cowpea prices adjust in markets according to demand and supply situation in the state.

Decomposition of variance for horizontal integrated markets

The results of variance decomposition for the selected urban markets against its component, like-wise, the selected rural markets against its component are presented in Table 14. The decomposition detailed for the selected urban markets are as follows: For Bida market, in the short-run (first quarter), a shock to price of cowpea in Bida market will account 84.48, 1.90, and 13.62% variations of fluctuation in prices at Bida (own shock), Minna and Kontagora markets, respectively; while in the long-run (last quarter), a shock to price in Bida market will account for 71.53, 2.43, and 26.03% variation of fluctuation in prices at Bida (own shock), Minna, and Kontagora markets, respectively. In the case of Minna market, in the short-run, an impulse to price of cowpea in Minna market can cause 9.93, 87.55, and 2.52% of variation in the fluctuation of prices in Bida, Minna (own shock), and Kontagora markets, respectively; while in the long-run (last quarter), an impulse to price in Minna market can cause 30.83, 56.41, and 12.76% of variation in the fluctuation of prices in Bida, Minna (own shock), and Kontagora markets, respectively. Furthermore, in the case of Kontagora market, in the short-run (first quarter), an innovation to the price in Kontagora market can cause 47.48, 1.25, and 51.28% of variation in the fluctuation of prices in Bida, Minna, and Kontagora (own shock), respectively; while in the long-run (last quarter), an innovation to price in Kontagora market can cause 61.35, 2.23, and 36.43% of variation in the fluctuation of prices at Bida, Minna, and Kontagora (own shock), respectively. For horizontal integrated rural markets: A shock to price of cowpea in Lefane market in the short-run (first quarter) can cause 84.96, 0.74, and 14.30% of variation in the fluctuation of prices in its own market, Zungeru, and Manigi markets, respectively; while in the long-run (last quarter) it can cause 73.37, 1.33, and 25.30% variation in the fluctuation of prices in its own market, Zungeru, and Manigi markets, respectively. A shock to price in Zungeru market in the short-run (first quarter) will cause 37.83, 54.77, and 7.40% of variation in the fluctuation of prices in Lefane market, its own market (Zungeru), and Manigi market, respectively; while in the long-run (last quarter) it will cause 56.39, 23.30, and 20.31% of variation in the fluctuation of prices in Lefane, Zungeru (own shock), and Manigi markets, respectively. Furthermore, an impulse on price in Manigi market in the short-run (first quarter) can cause 47.75, 0.51, and 51.74% of variation in the fluctuation of prices in Lefane, Zungeru, and Manigi (own shock) markets, respectively; while an impulse in the long-run can cause 63.19, 1.24, and 35.58% of variation in the fluctuation of prices in Lefane, Zungeru, and Manigi (own shock) markets,

Table 14: Decomposition of variance for horizontal integrated markets

Decomposition of variance for horizontal urban integrated markets											
Bida				Minna				Kontagora			
Period	Bida	Minna	Kontagora	Period	Bida	Minna	Kontagora	Period	Bida	Minna	Kontagora
1	100.00	0.000	0.000	1	0.749	99.251	0.000	1	28.783	0.092	71.125
2	90.873	1.460	7.667	2	5.793	93.263	0.944	2	40.594	0.783	58.623
3	84.482	1.902	13.615	3	9.931	87.547	2.523	3	47.478	1.247	51.275
4	80.502	2.088	17.410	4	13.425	82.435	4.140	4	51.669	1.541	46.790
5	77.916	2.193	19.891	5	16.481	77.888	5.631	5	54.408	1.735	43.857
6	76.133	2.261	21.606	6	19.198	73.827	6.976	6	56.317	1.871	41.813
7	74.838	2.310	22.852	7	21.634	70.180	8.186	7	57.717	1.970	40.313
8	73.856	2.347	23.798	8	23.832	66.889	9.279	8	58.786	2.046	39.168
9	73.086	2.376	24.538	9	25.825	63.903	10.271	9	59.629	2.106	38.264
10	72.467	2.399	25.134	10	27.642	61.183	11.175	10	60.311	2.155	37.534
11	71.958	2.418	25.624	11	29.304	58.694	12.002	11	60.874	2.195	36.931
12	71.532	2.434	26.034	12	30.831	56.407	12.762	12	61.346	2.229	36.426
Decomposition of variance for horizontal rural integrated markets											
Lefane				Zungeru				Manigi			
Period	Lefane	Zungeru	Manigi	Period	Lefane	Zungeru	Manigi	Period	Lefane	Zungeru	Manigi
1	100.00	0.000	0.000	1	24.555	75.446	0.000	1	25.581	0.026	74.394
2	91.0780	0.431	8.489	2	32.124	64.230	3.647	2	39.801	0.258	59.941
3	84.965	0.736	14.299	3	37.831	54.766	7.404	3	47.751	0.509	51.740
4	81.307	0.922	17.771	4	42.111	47.512	10.378	4	52.460	0.705	46.835
5	78.987	1.041	19.972	5	45.398	41.930	12.673	5	55.501	0.848	43.651
6	77.406	1.122	21.472	6	47.987	37.537	14.476	6	57.613	0.953	41.435
7	76.264	1.181	22.554	7	50.073	34.001	15.927	7	59.162	1.031	39.807
8	75.402	1.226	23.372	8	51.788	31.095	17.117	8	60.346	1.091	38.563
9	74.728	1.261	24.011	9	53.221	28.666	18.113	9	61.282	1.139	37.580
10	74.187	1.289	24.524	10	54.437	26.607	18.957	10	62.039	1.178	36.784
11	73.743	1.312	24.945	11	55.481	24.837	19.681	11	62.664	1.210	36.127
12	73.372	1.331	25.297	12	56.388	23.302	20.311	12	63.189	1.236	35.575

respectively. Furthermore, results clearly show that the shock originating from a respective market at both time periods is more pronounced on the respective market itself when compared to its effect on other markets.

Decomposition of variance for vertical integrated markets

Table 15 shows the result of variance decomposition for the vertically integrated cowpea markets in the state. A cursory review of the results for Bida-Lafene market pair show that a shock to the price in Bida market in the short-run (first quarter) can cause 84.20 and 15.80% of variation in the fluctuation of prices on its own market and Lefane market, respectively, while in the long-run (last quarter) it will cause 77.54 and 22.46% of variation in the fluctuation of prices in its own market and Lefane market, respectively. In the reverse situation, a shock to price in Lafene market in the short-run (first quarter) can cause 67.01 and 32.99% of variation in the fluctuation of prices in Bida market and on its own market, respectively; while in the long-run (last quarter) it will cause 73.03 and 26.97% of variation in fluctuation of prices in Bida and Lefane markets, respectively. For Minna-Zungeru market pair, an innovation to price in Minna market in the short-run (first quarter) can cause 84.37 and 15.63% of variation in the fluctuation of prices in Minna and Zungeru markets, respectively; while in the long-run (last quarter) it can cause 50.46 and 49.54% of variation in the fluctuation of prices in Minna

Table 15: Decomposition of variance for vertical integrated markets

Bida			Lefane			Minna			Zungeru		
Period	**Bida**	**Lefane**	**Period**	**Bida**	**Lefane**	**Period**	**Minna**	**Zungeru**	**Period**	**Minna**	**Zungeru**
1	100.00	0.000	1	50.747	49.253	1	100.00	0.000	1	11.538	88.463
2	88.028	11.972	2	63.151	36.849	2	91.931	8.070	2	9.884	90.116
3	84.196	15.804	3	67.014	32.986	3	84.366	15.634	3	9.881	90.119
4	82.090	17.910	4	68.998	31.002	4	78.030	21.970	4	9.921	90.079
5	80.776	19.224	5	70.198	29.802	5	72.687	27.313	5	9.950	90.051
6	79.877	20.777	6	71.003	28.997	6	68.123	31.877	6	9.970	90.031
7	79.223	20.777	7	71.580	28.420	7	64.179	35.821	7	9.984	90.016
8	78.726	21.274	8	72.014	27.986	8	60.737	39.263	8	9.996	90.004
9	78.335	21.665	9	72.352	27.648	9	57.707	42.293	9	10.005	89.995
10	78.020	21.980	10	72.623	27.377	10	55.019	44.981	10	10.012	89.988
11	77.761	22.239	11	72.845	27.155	11	52.618	47.382	11	10.018	89.982
12	77.544	22.456	12	73.031	26.970	12	50.461	49.539	12	10.024	89.977
Kontagora			**Manigi**								
Period	**Kontagora**	**Manigi**	**Period**	**Kontagora**	**Manigi**						
1	100.00	0.000	1	49.961	50.040						
2	94.360	5.640	2	59.803	40.198						
3	89.911	10.089	3	64.800	35.200						
4	87.038	12.962	4	67.636	32.364						
5	85.144	14.856	5	69.414	30.586						
6	83.828	16.172	6	70.619	29.381						
7	82.867	17.133	7	71.487	28.513						
8	82.136	17.864	8	72.141	27.860						
9	81.561	18.439	9	72.651	27.350						
10	81.098	18.902	10	73.060	26.940						
11	80.716	19.284	11	73.395	26.605						
12	80.397	19.604	12	73.675	26.326						

and Zungeru markets, respectively. While a shock to price in Zungeru market in the short-run (1st quarter) can cause 9.88 and 90.12% of variation in the fluctuation of prices in Minna and Zungeru markets, respectively; while in the long-run (last quarter) it can cause 10.02 and 89.98% of variation in the fluctuation of prices in Minna and Zungeru markets, respectively. For Kontagora-Manigi market pair, a shock on Kontagora market in the short-run (first quarter) can cause 89.91 and 10.09% of variation in the fluctuation of prices in Kontagora and Manigi markets, respectively; while in the long-run it can cause 80.40 and 19.60% of variation in the fluctuation of prices in Kontagora and Manigi markets, respectively. A shock to price in Manigi market in the short-run (first quarter) can cause 64.80 and 35.20% of variation in the fluctuation of prices in Kontagora and Manigi markets, respectively; while in the long-run (fourth quarter) it can cause 73.68 and 26.33% of variation in the fluctuation of prices in Kontagora and Manigi markets, respectively.

Impulse response functions for horizontal and vertical integrated markets

The estimation of impulse response function was inconsistent at the long horizon when estimated from the unrestricted VAR if there was unit root or cointegration. Hence, the stable impulse response function was derived from the error correction model. The results of impulse response functions are shown in Figures 1a-c show how and to what extent a standard deviation shock in one of the markets affects the current as well as future prices in all the integrated markets over a period of 12 months [Figures 1d-e]. The graph indicate that unexpected shock on price that is local to any of the selected horizontal integrated urban market will have transitory effect on its own market

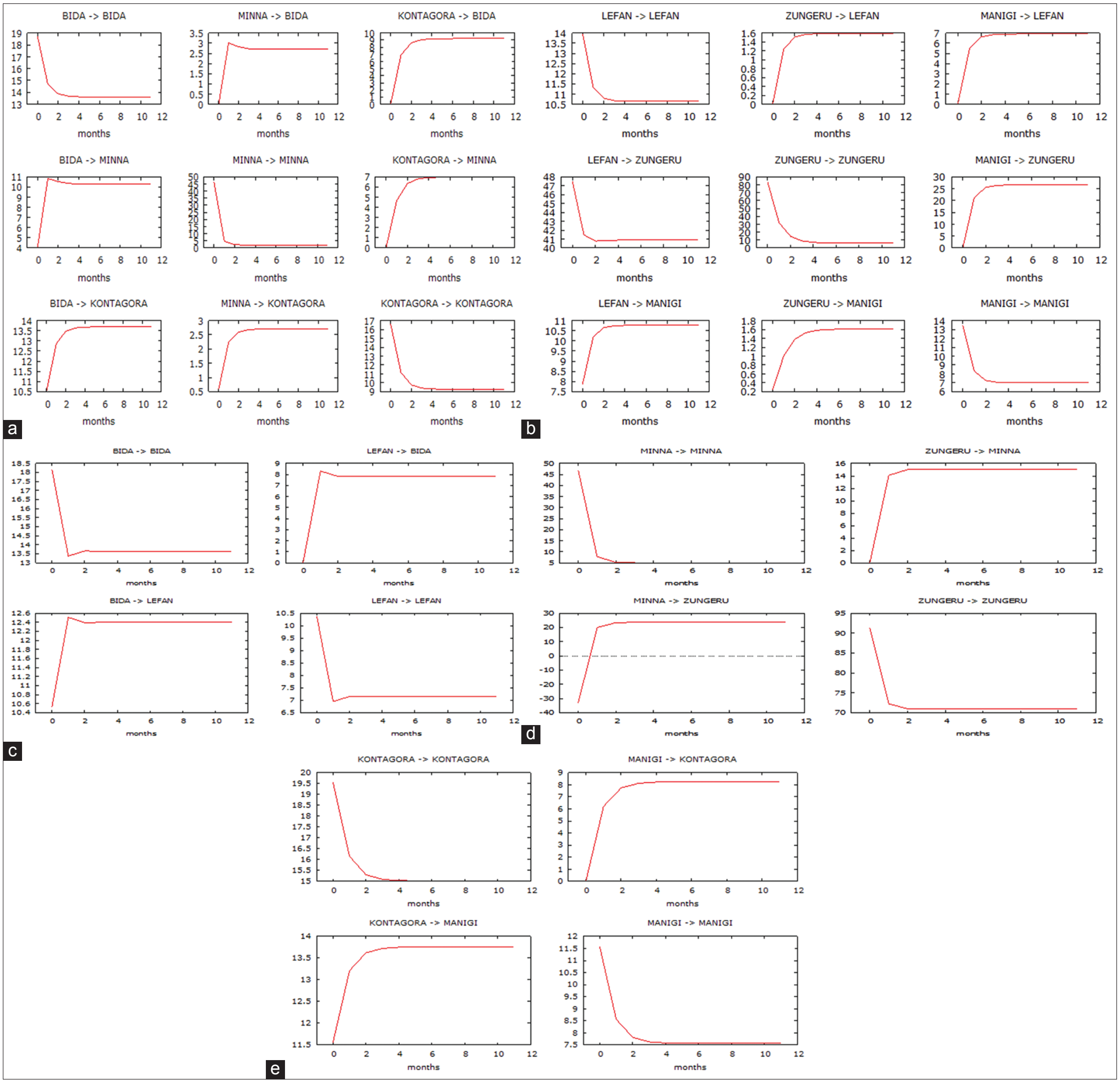

Figure 1: (a) HUMI (row 1 column 1–row 3 column 3); (b) HRMI (row 1 column 4–row 3 column 6); (c) BVI Bida-Lefane markets (row 4 column 1–row 5 column 2); (d) BVI Minna-Kontagora markets (row 4 column 3–row 5 column 4); (e) BVI Kontagora-Manigi markets below: HIU/RM: Horizontal integrated urban/rural market, BVI: Bivariate vertical integrated

(i.e., the effect of the shock would die out over time) and a permanent effect on the other urban markets (i.e., the effect of the shock would not die out over time). Furthermore, an orthogonalized shock to the price of any of the selected horizontal integrated rural markets will have a transitory effect on its own market and a permanent effect on the other rural markets. And when a standard deviation shock is given to any of the vertically integrated markets, the response of the other market in the pair will be permanent, while the response on its own market will be transitory.

Diagnostic testing

The results of the diagnostic statistics of VECM models for horizontal integrated and vertically integrated markets are presented in Table 16. The autocorrelation test for each VECM model indicates that the residuals are not serially correlated as evidenced by the Ljung-Box Q-statistics, which are not different from zero at 10% probability level ($P > 0.10$), thus indicating no autocorrelation. The Arch tests for each VECM models revealed that there is no information transmission

Table 16a: VECM diagnostic checking for horizontal integrated rural markets

Test	Statistic	*P*-value
Multivariate horizontal integrated rural market		
Autocorrelation		
Ljung-box Q (Eq. 1)	5.944	0.968
Ljung-box Q (Eq. 2)	18.489	0.185
Ljung-box Q (Eq. 3)	19.802	0.137
Arch effect		
LM-test (Eq. 1)	0.0282	0.867
LM-test (Eq. 2)	2.555	0.120
LM-test (Eq. 3)	0.059	0.808
Eigenvalues		
1	0.4119	
2	0.7355	
3	1.8526	
Normality		
Doornik-Hansen test	530.635	0.000
Pair-wise horizontal integrated rural market		
Lefane-Zungeru		
Autocorrelation		
Ljung-box Q (Eq. 1)	13.398	0.341
Ljung-box Q (Eq. 2)	13.650	0.324
Arch effect		
LM-test (Eq. 1)	0.047	0.828
LM-test (Eq. 1)	2.170	0.141
Normality		
Doornik-Hansen test	475.379	0.000
Lefane-Manigi		
Autocorrelation		
Ljung-box Q (Eq. 1)	4.269	0.978
Ljung-box Q (Eq. 2)	19.705	0.073
Arch effect		
LM-Test (Eq. 1)	0.0222	0.8882
LM-Test (Eq. 1)	0.0558	0.813
Normality		
Doornik-Hansen test	160.627	0.000
Zungeru-Manigi		
Autocorrelation		
Ljung-box Q (Eq. 1)	21.422	0.124
Ljung-box Q (Eq. 2)	26.459	0.034
Arch effect		
LM-test (Eq. 1)	3.481	0.176
LM-test (Eq. 1)	0.114	0.945
Normality		
Doornik-Hansen test	482.098	0.000

VECM: Vector error correction model

Table 16b: VECM diagnostic checking for horizontal integrated urban markets

Test	Statistic	*P*-value
Multivariate horizontal integrated urban market		
Autocorrelation		
Ljung-box Q (Eq. 1)	5.838	0.924
Ljung-box Q (Eq. 2)	12.1	0.438
Ljung-box Q (Eq. 3)	14.959	0.244
Arch effect		
LM-test (Eq. 1)	0.739	0.390
LM-test (Eq. 2)	0.066	0.797
LM-test (Eq. 3)	0.030	0.862
Eigenvalues		
1	0.463	
2	0.976	
3	1.560	
Normality		
Doornik-Hansen test	4471.56	0.000
Pair-wise horizontal integrated urban market		
Bida-Minna		
Autocorrelation		
Ljung-box Q (Eq. 1)	13.270	0.35
Ljung-box Q (Eq. 2)	11.728	0.468
Arch effect		
LM-test (Eq. 1)	9.079	0.696
LM-test (Eq. 1)	1.089	0.999
Normality		
Doornik-Hansen test	3957.75	0.000
Bida–Kontagora		
Autocorrelation		
Ljung-box Q (Eq. 1)	6.328	0.899
Ljung-box Q (Eq. 2)	14.682	0.259
Arch effect		
LM-test (Eq. 1)	0.785	0.376
LM-test (Eq. 1)	0.038	0.846
Normality		
Doornik-Hansen test	602.934	0.000
Minna–Kontagora		
Autocorrelation		
Ljung-box Q (Eq. 1)	11.05	0.525
Ljung-box Q (Eq. 2)	24.54	0.017
Arch effect		
LM-test (Eq. 1)	0.128	0.721
LM-test (Eq. 1)	0.0045	0.947
Normality		
Doornik-Hansen test	3654.55	0.000

VECM: Vector error correction model, LM: LM: Lagrange multiplier

Table 16c: VECM Diagnostic checking for pair-wise vertical integrated markets

Test	Statistic	*P*-value
Bida–Lefane		
Autocorrelation		
Ljung-box Q (Eq. 1)	9.246	0.682
Ljung-box Q (Eq. 2)	12.802	0.384
Arch effect		
LM-test (Eq. 1)	0.122	0.727
LM-test (Eq. 1)	0.076	0.782
Normality		
Doornik-Hansen test	329.154	0.000
Minna-Zungeru		
Autocorrelation		
Ljung-box Q (Eq. 1)	16.134	0.185
Ljung-box Q (Eq. 2)	17.294	0.139
Arch effect		
LM-test (Eq. 1)	0.101	0.951
LM-test (Eq. 1)	4.182	0.124
Normality		
Doornik-Hansen test	2271.83	0.000
Kontagora–Manigi		
Autocorrelation		
Ljung-box Q (Eq. 1)	17.909	0.118
Ljung-box Q (Eq. 2)	21.861	0.039
Arch effect		
LM-test (Eq. 1)	0.066	0.797
LM-test (Eq. 1)	0.040	0.841
Normality		
Doornik-Hansen test	346.548	0.000

VECM: Vector error correction model, LM: Lagrange multiplier

between the preceding and succeeding residuals as evidenced from the Lagrange multiplier test statistics which were not different from zero at 10% probability level ($P > 0.10$), thus indicating no Arch effects are present. Furthermore, the stability tests indicated that none of the models was misspecified as evidence from the Eigenvalues, which shows that none of the remaining Eigenvalues appears close to the unit circle. Furthermore, the result of normality test for each VECM model indicated that the residuals are not normally distributed as evidence from Doornik-Hansen test Chi-square which is different from zero at 10% probability level ($P < 0.10$). However, when dealing with time-series data, non-normality of the residuals is not considered a serious problem, because in most cases these data are not normally distributed. Therefore, based on the outcome of the diagnostic statistics, it can be inferred that all the results were valid as all the models used were the best fit.

Forecasting using VECM

Diagnostic checking

The model verification is concerned with checking the residuals of the model to see if they contained any systematic pattern which still could be removed to improve the VECM [Table 17a]. This was done, namely, investigating the autocorrelations and partial autocorrelations of the residuals at various lags. Using the computed values, it was found that these autocorrelations were not significantly

Table 17a: One step ahead forecast of prices

Date	Bida market		Minna market		Kontagora market	
Urban market prices						
	Actual	Forecast	Actual	Forecast	Actual	Forecast
2016:08	285.51	284.22	200.98	226.94	291.50	287.89
2016:09	285.51	285.95	200.98	228.44	291.50	290.34
2016:10	284.87	285.95	224.72	228.44	277.05	290.34
2016:11	284.87	281.02	226.13	226.44	248.10	281.38
2016:12	274.46	269.05	221.42	218.45	187.20	261.97
Rural market prices						
Date	Lefane market		Zungeru market		Manigi market	
	Actual	Forecast	Actual	Forecast	Actual	Forecast
2016:08	250.42	249.00	754.59	798.97	253.36	251.93
2016:09	250.42	250.30	754.59	803.69	253.36	253.79
2016:10	249.53	250.30	736.76	803.69	240.80	253.79
2016:11	241.53	244.46	774.79	776.39	216.34	245.53
2016:12	213.47	230.72	818.39	745.95	252.01	228.01

different from zero [Table 16a-b]. These proved that the VECM model was an appropriate model for forecasting the data under study.

Validation

One-step ahead forecast of price along with their corresponding standard errors using naïve approach for the period August 2016–December 2016 (total five data points) in respect of the VECM fitted models was computed.

Table 17b: Validation of models

Market	R^2	MAPE	RMSPE	RMAPE (%)
Bida	0.99	1.806	0.034	0.65
Minna	0.99	10.90	1.44	5.41
Kontagora	0.98	23.31	7.00	9.30
Lafene	0.99	3.88	0.29	1.80
Zungeru	0.99	17.91	3.66	3.2
Manigi	0.99	3.44	1.39	1.8

Source: Authors computation, 2017, RMAPE: Relative mean square prediction error, MAPE: Mean absolute prediction error

The forecasting ability of the VECM models of price series for the urban and rural markets was judged on the basis of MAPE, root mean square error, and RMAPE values [Table 17b]. A perusal of Table 17b shows that for all the price series variables, RMAPE is <10%, indicating the accuracy of the VECM models used.

Forecasting

One step ahead out of sample forecast of cowpea price (₦/Kg) for the urban and rural markets during the January 2017–December 2017 has been computed. The actual data points are shown

Table 17c: Out of sample forecast of cowpea prices in selected urban and rural markets (₦/Kg)

Price forecast of cowpea in urban markets									
Date	Bida market			Minna market			Kontagora market		
	Forecast	UCL	LCL	Forecast	UCL	LCL	Forecast	UCL	LCL
2017:01	237.85	274.54	201.15	196.73	287.43	106.03	217.72	256.31	179.13
2017:02	229.44	278.35	180.53	188.28	282.32	94.24	226.29	277.50	175.07
2017:03	227.99	286.71	169.27	186.51	283.69	89.33	229.20	290.13	168.26
2017:04	228.32	295.48	161.15	186.57	286.82	86.33	230.65	299.88	161.41
2017:05	229.10	303.78	154.42	187.12	290.35	83.88	231.72	308.36	155.08
2017:06	230.00	311.50	148.50	187.78	293.92	81.65	232.70	316.08	149.32
2017:07	230.93	318.73	1143.13	188.48	297.44	79.52	233.65	323.27	144.04
2017:08	231.87	325.54	138.19	189.19	300.91	77.47	234.60	330.05	139.16
2017:09	232.81	332.01	133.60	189.90	304.30	75.49	235.55	336.49	134.61
2017:10	233.75	338.18	129.31	190.61	307.64	73.58	236.49	342.64	130.35
2017:11	234.69	344.11	125.26	191.32	310.92	71.72	237.44	348.55	126.33
2017:12	235.63	349.82	121.44	192.03	314.15	69.91	238.39	354.25	122.52
Price forecast of cowpea in rural markets									
Date	Lefane market			Zungeru market			Manigi market		
	Forecast	UCL	LCL	Forecast	UCL	LCL	Forecast	UCL	LCL
2017:01	230.85	258.19	203.50	796.70	984.33	609.08	240.82	271.39	210.25
2017:02	235.29	272.20	198.38	784.49	1002.38	566.60	239.69	279.74	199.63
2017:03	237.03	281.60	192.47	781.56	1020.73	542.90	240.40	287.84	192.96
2017:04	238.22	289.35	187.09	782.95	1040.99	524.90	241.41	295.21	187.62
2017:05	239.29	296.23	182.34	786.01	1061.52	510.50	242.47	301.94	182.99
2017:06	240.33	302.55	178.11	789.68	1081.59	497.77	243.52	308.17	178.86
2017:07	241.37	308.45	174.28	793.55	1100.98	486.12	244.57	314.02	175.12
2017:08	242.40	314.02	170.79	797.50	1119.70	475.30	245.62	319.55	171.68
2017:09	243.44	319.32	167.56	801.47	1137.79	465.15	246.66	324.83	168.50
2017:10	244.47	324.39	164.56	805.45	1155.31	455.58	247.71	329.89	165.54
2017:11	245.51	329.27	161.75	809.43	1172.34	446.52	248.76	334.76	162.76
2017:12	246.55	333.97	159.12	813.41	1188.91	437.91	249.81	339.46	160.15

UCL: Upper confidence limit, LCL: Lower confidence limit

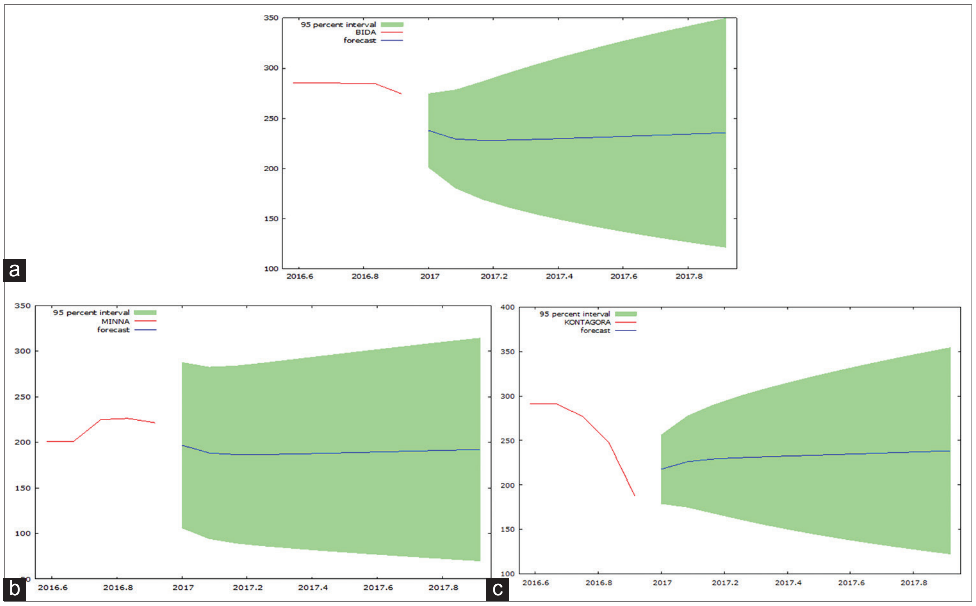

Figure 2: (a) Price forecast of cowpea in Bida market, (b) price forecast of cowpea in Minna market, (c) price forecast of cowpea in Kontagora market. Note row-wise: Figure 2a, 2b, 2c, are price forecasts of cowpea in Bida, Minna, Kontagora, Lefane, Zungeru, and Manigi markets, respectively

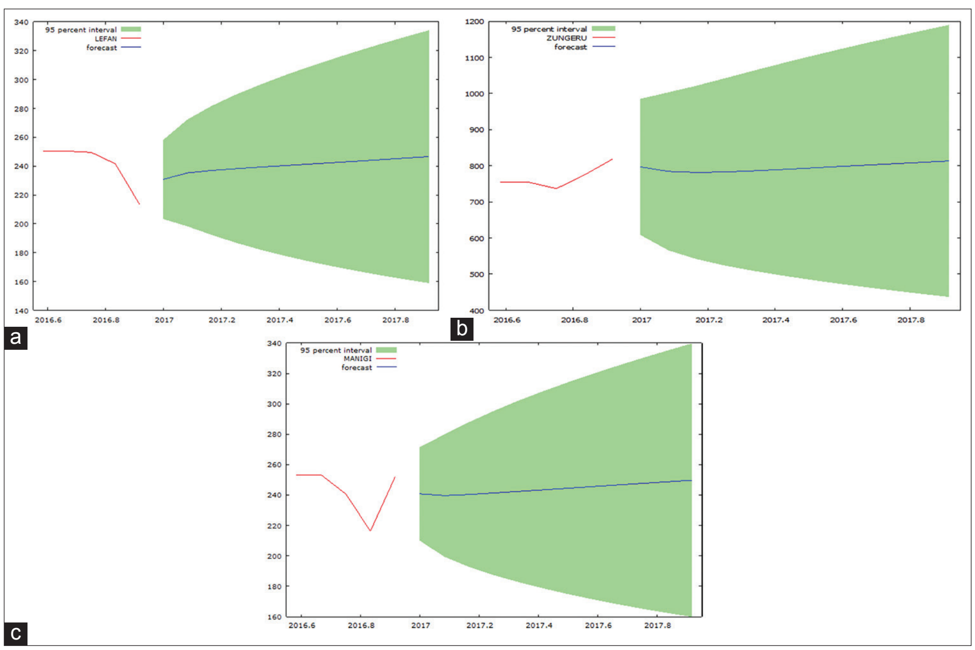

Figure 3: (a) Price forecast of cowpea in Lefan market, (b) price of cowpea in Zungeru market, (c) price forecast of cowpea in Manigi market. Note row-wise: Figure 3a, 3b, 3c are price forecasts of cowpea in Bida, Minna, Kontagora, Lefane, Zungeru, and Manigi markets, respectively

in Table 17c and also depicted in Figures 2 and 3 to visualize the performance of the fitted model. A cursory review shows that prices of cowpea in all the markets with the exception of Zungeru market will be marked by slight variation, i.e., will witness slight variation as evidenced by the standard error values. Further, in the situation of bad-news (inflation), the prices in each of the market would not exceed its respective price upper limit, and in the case of good-news (administered prices), the prices in each of the market would not go below its respective price lower limit. For policy implication, the government should put in place mechanism to checkmate virulent price instability that will occur in Zungeru market to protect itself and all market participants, even though this kind of measure will amount to the creation of imperfection in cowpea market in the state.

CONCLUSIONS AND RECOMMENDATIONS

The present study focused on price transmission and signals of three major urban cowpea markets and their respective adjunct rural markets across the zones and value chain in Niger state of Nigeria. The results showed that the markets both at horizontal and vertical integration levels were integrated of order one, i.e., at the level they were non-stationary, but at first difference, they became stationary, thus, justifying the use of cointegration test. The cointegration test results of the markets both at horizontal and vertical integration levels proved that despite that these markets were spatially separated geographically they were well connected in terms of price transmission across them. Furthermore, it was observed that almost all the ECTs were statistically significant, meaning that the system once in disequilibrium tries to come back to the equilibrium situation. This coefficient (ECT), known as the attractor, helps absorb the effects of shocks and keeps prices in a long-term equilibrium relationship. The higher the attractor (in absolute value), the faster the speed of price adjustment toward its equilibrium level. Virtually under all scenarios, Bida market was found to be more price and operationally efficient that all the selected urban markets because of its close proximity to the largest terminal markets for cowpea in the country, i.e., Lagos state and other states in the southwest of Nigeria. Low pricing efficiency of cowpea in Minna market is associated with "bull raid" activities of the traders, while the low pricing efficiency of Kontagora market can be attributed to the dampening effects caused by the glut in the leading cowpea producing markets in the country which are located in the neighboring states, i.e., Kebbi, Sokoto, Zamfara all in the northwestern part of the country. However, the rates of adjustments for most of the markets were high when prices were influenced by the changes in each other's price. Based on findings it can be inferred that the price signals are transmitted across zones and value chains, i.e., price changes in one zone are consistently related to the price changes in other zones and are able to influence the prices in other zones. However, the direction and intensity of price changes may be affected by the dynamic linkages between the demand and supply of cowpea. The market outlook in terms of forecast and attendant volatility for all the markets except Zungeru markets looks bright and promising, as indicated by their respective standard deviation values which were small. The insights from this study can be used to improve the information precision to predict the price movements used by marketing operators for their strategies. Furthermore, the policymakers can use it to design suitable marketing strategies to bring more efficiency to the markets.

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