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Research Article

Generating Market Information and Market Outlook of Major Cassava Markets in Africa: A Direction for Nigeria Trade Investment and Policy

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Abstract

The research investigated market integration, price volatility and price discovery across four major cassava markets viz. Ghana, Nigeria, Madagascar and Rwanda in Africa using Johansen's multivariate cointegration approach; GARCH and ARIMA models. Yearly time series data spanning from 1991 - 2014 sourced from FAOSTAT data bank were used. Findings confirmed the presence of cointegration, implying long-run price association among these markets. For additional evidence as to whether and in which direction price transmission is occurring between the market pairs, Granger causality test indicated four unidirectional causalities; Ghana-Rwanda; Madagascar-Nigeria and Madagascar-Rwanda markets, no existence of bidirectional causality, while the remaining market pairs showed no causal relation between them. The impulse response functions conducted confirmed the result of cointegration, but the magnitude of price transmission was found relatively low in some market pairs that are spatially integrated. Further, findings indicated usefulness of cassava trading in the major cassava markets in Africa given that explosive volatility pattern was not observed. Also, findings revealed that ARIMA model could be used successfully for modelling as well as forecasting of yearly prices of cassava in the major markets in Africa given its good performance in terms of explained variability and predicting power. Based on findings, network design for major cassava markets across Africa at almost equal distance from each other to enhance market integration and better price transmission among them was recommended. Also, the high degree of market integration observed in this case indicate that the major cassava markets in Africa are quite competitive, thus, providing little justification for extensive and costly intervention designed to enhance market efficiency via improve competition.

Keywords: Cointegration; Efficient Market; Volatility; Forecast; Cassava; Africa

Introduction

Market intelligence is an essential function for the formulation of a sound price and trade policy, and its successful implementation. It serves as a mechanism for understanding the behaviour of relevant factors; and helps in the evolution of a proper pricing policy and generating outlook information. Market information creates competitive market process and checks the growth of monopoly or profiteering by individuals. It is the lifeblood of a market, because everyone engaged in production, and in buying and selling of products is continually in need of market information. This is truer where agricultural commodities are concerned, because their prices fluctuate more widely than those products of other sectors. The research in agricultural marketing in sub-Saharan Africa, particularly of applied nature, has been meagre and scanty because of the strenuous and time-consuming job of collecting and maintaining a credible data from different market functionaries, because in most cases market functionaries are not ready to part with correct information and data, thus, making marketing research in sub-Saharan Africa not to make headway for long, as such, a lot of scope exists for research in this field. At present, agricultural marketing research in sub-Saharan Africa is both descriptive and analytical. A description of facts enables us to understand 'what' the system is, but not the 'why' part of it. The structural interrelationships among the various variables of the system have to be understood. Therefore, there is an urgent need for an analysis of the most relevant variables in marketing research. This research need looks into the perspective of cassava marketing in sub-Saharan Africa considering its nascent stage.

Examples of studies on cassava marketing are [1-4] but the major drawback is that all these studies focused on domestic marketing of this product; with no evidence based studies on international trade outlook of this commodity despite its emerging market potentials in the world. It is a known fact that the need for research in cassava marketing has been recognized by the planners and policy makers, given that, research in this aspect can contribute to the establishment of facts and evolution of the policy measures that may be necessary for developing a successful marketing strategy with respect to production, consumption, distribution and pricing. A smooth functioning of the marketing system is essential for price stability and for proper incentives to the producers. In the present context, when agricultural production is on the increase, the marketing system should be suitably altered to sustain the increase by providing efficient and prompt services. This can be achieving by keeping a constant watch on developments and by anticipating the problems in marketing of this commodity. Market information is essential for the government, for creating a policy environment for a smooth conduct of the marketing business, and for the protection of all the groups of persons associated with this. Also, it is essential at all the stages of marketing, from the sale of the produce at the farm until the goods reach the last/final consumer.

Data and Methodology

Africa is a continent comprising 63 political territories, representing the largest of the great southward projections from the main mass of Earth's surface. Within its regular outline, it comprises an area of 30,368,609 km^2 (11,725,385 sq mi), including adjacent islands. The climatic conditions favour agricultural activities such as crop production, animal husbandry, horticulture, apiculture etc. this study made use of time series data. Yearly data on producer cassava prices ($/tons) in Ghana, Nigeria, Madagascar and Rwanda markets spanning from 1991 to 2014 were sourced from the FAOSTAT databank. Analytical techniques used are described below:

Empirical Models

(1) Model Selection Criteria

The information criteria are computed for the VAR models of the form:

$$Yt = A1Yt\text{-}1 + \dots + AnYt\text{-}n + Bq\,Xt + \dots\dots + BqXt\text{-}q + CDt + \mathcal{E}t \quad \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where Yt is K-dimensional. The lag order of the exogenous variables Xt, q, and deterministic term Dt have to be pre-specified. For a range of lag orders n the model is estimated by OLS. The optimal lag is chosen by minimizing one of the following information criteria:

$$AIC\ (n) = \log\det\{\textstyle\sum_u(n)\} + (2/T)\ nK^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$HQ\ (n) = \log\det\{\textstyle\sum_u(n)\} + (2\log\log T/T)\ nK^2 \quad \dots\dots\dots\dots\dots\dots (3)$$

$$SC\ (n) = \log\det\{\textstyle\sum_u(n)\} + (\log T/T)\ nK^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots (4)$$

$$FPE\ (n) = (T + n^*/T\text{-}n^*)^k \det\{\textstyle\sum_u(n)\} \quad \dots\dots\dots\dots\dots\dots\dots\dots (5)$$

Where $\sum_u(n)$ is estimated by $T^{-1} \sum^{T}_{(t=1} UtU^1t$, n* is the total number of parameters in each equation of the model when n is the lag order of the endogenous variables, also counting the deterministic terms and exogenous variables. The sample length is the same for all different lag lengths and is determined by the maximum lag order.

(2) Augmented Dickey Fuller Test

The Augmented Dickey-Fuller test (ADF) is the test for the unit root in a time series sample [5]. The autoregressive formulation of the ADF test with a trend term is given below:

$$\Delta pt = \alpha + pt\text{-}1 + \textstyle\sum^{it}_{j=2} \beta i \Delta p_{it\text{-}j+t} + \mathcal{E} \quad \dots\dots\dots\dots\dots\dots (6)$$

Where, pit is the price in market i at the time t, Δp_{it} (p_{it} - p_t-1) and α is the intercept or trend term. The joint hypothesis to check the presence of unit root is: H_0: $\gamma = \alpha_0 = 0$ using φ_1 statistic. Failure of the rejection of null hypothesis means that the series is non-stationary.

(3) Johansen's Co-integration Test

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

$$p_t = A_1\, p_{t-1} + \mathcal{E}_t \quad \dots\dots\dots\dots\dots\dots\dots\dots (7)$$

So that

$$\Delta p_t = A_1\, p_{t-1} - p_{t-1} + \mathcal{E}_t \quad \dots\dots\dots\dots\dots\dots (8)$$

$$p_t = (A_1 - I)\, p_{t-1} + \mathcal{E}_t \quad \dots\dots\dots\dots\dots\dots\dots\dots (9)$$

$$\Delta p_t = \textstyle\prod p_{t-1} + \mathcal{E}_t \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (10)$$

Where, p_t and $\mathcal{E}_t$ are (n×1) vectors; At is an (n x n) matrix of parameters; I is an (n x n) identity matrix; and ∏ is the (A_1-1) matrix. The rank of (A_t -1) matrix equals the number of co-integrating vectors. The crucial thing to check is whether (A_1-1) consists of all zeroes or not. If it does, then it implies that all the {p_t} in the above VAR are unit root processes, and there is one linear combination of which is stationary, and hence the variables are not co-integrated. The rank of matrix ∏ is equal to the number of independent co-integrating vectors. Both trace and max test were used to determine the presence of co-integrating relationship among and between the price series. 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:

$$\lambda_{trace} = \text{-}T \textstyle\sum^{n}_{(i=r+1)} \ln(1\text{-}\lambda i) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (11)$$

$$\lambda_{max} = \text{-}T \ln(1\text{-}\lambda_i + 1) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (12)$$

Where, λ_i denotes the estimated values of the characteristic roots (eigen values) obtained from the estimated ∏ matrix; and T is the number of usable observations.

(4) Biochemical Estimations

[6] causality test was used to determine the order and direction of short-term and long-term equilibrium relationships. Whether market *p1* Granger causes market *p2* or vice-versa was checked using the following model:

$$p_t = c + \sum^{n}_{(i=1)}(\varphi\, p1_{t-i} + \delta_i\, p2_{t-i}) + \varepsilon_i \text{ .... (13)}$$

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

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

(5) Vector Error Correction Model (VECM)

After establishing the multiple co-integrating relationships among price series, Vector Error Correction Model (VECM) was constructed to determine the short-term disturbances and the adjustment mechanism to estimate the speed of adjustment. The VECM explains the difference in yt and yt-1 (i.e. Δyt) and it is shown below:

$$\Delta y_t = a + \mu(y_{t-1} - \beta x_{t-1}) + \sum_{i=0}^{i=t}\delta_i\,\Delta x_{t-1} + \sum_{i=1}^{i=t}\gamma_i \Delta y_{t-1} \quad ---(14)$$

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

For example, if Δxt increases by one percentage point, then Δyt would increase by δ percentage point. The value of β indicates the percentage point would change in the long-run in response to changes in x.

Therefore, part of the change in Δy_t could be explained by y correcting itself in each period to ultimately reach the long-run path with x. The amount by which the value of y changes (or corrected) in each period is signified by μ. This coefficient (μ) indicates the percentage of the remaining amount that y has to move to return to its long-run path with x. In explaining changes in a variable, the VECM accounts for its long-run relationship with other variables. The advantage of VECM over an ordinary OLS model is that it accounts for dynamic relationships that may exist between a dependent variable and explanatory variable, which may span several periods.

(6) Impulse Response Functions

Granger causality tests do not determine the relative strength of causality effects beyond the selected time span. In such circumstances, causality tests are inappropriate because these tests are unable to indicate how much feedback exists from one variable to the other beyond the selected sample period [7,8]. The best way to interpret the implications of the models for patterns of price transmission, causality and adjustment are to consider the time paths of prices after exogenous shocks, i.e. impulse responses [8] impulse response function traces the effect of one standard deviation or one-unit shock to one of the variables on current and future values of all the endogenous variables in a system over various time horizon [9]. For this study, the generalized impulse response function (GIRF) originally developed by [10] and suggested by [11] was used. The GIRF in the case of an arbitrary current shock, δ, and history, ω_{t-1} is specified below:

$$GIRF_Y(h, \delta, \omega_{t-1}) = E[Y_t + h/\delta, \omega_{t-1}] - E[y_{t-1}/\omega_{t-1}] \text{ .... (15)}$$

For n = 0, 1

(7) GARCH Model

The representation of the GARCH (p, q) is given as:

$$Y_t = \alpha + b_1 Y_{t-1} + b_2 Y_{t-2} + \varepsilon_i \text{ (Autoregressive process) .... (16)}$$

And the variance of random error is:

$$\sigma^2 t = \lambda_0 + \lambda_1\, \mu^2_{t-1} + \lambda_2 \sigma^2_{t-1} \text{ .... (17)}$$

$$\sigma^2 t = \omega + \sum^{p}_{i=1}\beta i \sigma^2_{t-i} + \sum^{q}_{j=1}\alpha_i\, \varepsilon^2_{t-i} \text{ .... (18)}$$

Where, Y_t is the price in the i[th] period of the i[th] market, p is the order of the GARCH term and q is the order of the ARCH term. The sum of (α + β) gives the degree of persistence of volatility in the series. The closer is the sum to 1; the greater is the tendency of volatility to persist for a longer time. If the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from the mean value.

(8) ARIMA Model

A generalization of ARMA models which incorporates a wide class of non-stationary time-series is obtained by introducing the differencing into the model. The simplest example of a non-stationary process which reduces to a stationary one after differencing is Random Walk. A process $\{y_t\}$ is said to follow an integrated ARMA model, denoted by ARIMA (p, d, q), if $\nabla^d y_t = (1-\beta)^d \varepsilon_t$ is ARMA (p, q), and the model is written below:

$$\varphi(\beta)\,(1-\beta)^d\, y_t = \theta(\beta)\, \varepsilon_t \text{ ....(19)}$$

Where, $\varepsilon_t \sim WN(0,\sigma^2)$, and WN indicates white noise. The integration parameter d is a non-negative integer. When d = 0, ARIMA (p, d, q) = ARMA (p, q).

Forecasting Accuracy

For measuring the accuracy in fitted time series model, mean absolute prediction error (MAPE), relative mean square prediction error (RMSPE) and relative mean absolute prediction error (RMAPE) were computed using the following formulae [12]:

$$MAPE = 1/T \sum \{A_t - F_t\} \text{ .... (20)}$$

$$RMPSE = 1/T \sum \{(A_t - F_t)2 / A_t\} \text{ .... (21)}$$

$$RMAPE = 1/T \sum \{(A_t - F_t) / A_t\} X\ 100 \ldots\ldots\ldots\ldots (22)$$

Where, At = Actual value; Ft = Future value, and T= Time period(s)

Results and Discussion

Summary statistics of yearly producer prices of cassava in major cassava markets in Africa

The summary statistics of yearly prices of cassava spanning from 1991 to 2014 are presented in Table 1. The perusal of Table 1 reveals that the minimum values of the average prices varied from $38.96 per ton in Ghana market to $120.77 per ton in Nigeria market, while the maximum values of the average prices varied from $200.00 per ton in Madagascar market to $541.90 per ton in Nigeria market during the period under consideration. The average prices were found to be $111.99 per ton in Ghana market, $219.78 per ton in Nigeria market, $130.13 per ton in Madagascar market and $228.30 per ton in Rwanda market. The standard deviation in prices was found to be minimum in Madagascar market ($40.99 per ton) and maximum in Nigeria market ($122.70 per ton) during the period under consideration. Slight instability in cassava prices were noticed in all the selected markets, with it being highest in Nigeria market during the period under consideration, which might be due to fluctuation in arrivals as a result of seasonality. All the selected markets exhibited positively skewed distribution in their respective prices from year 1991 to 2014. Almost all the selected markets showed a platykurtic (fat or short-tailed) probability distribution function except Nigeria market which showed a leptokurtic (slim or long-tailed) pattern of distribution for the entire period under consideration.

Market	Min	Max	Mean	STD	CV	Skewness	Kurtosis	IQ range
Ghana	38.96	210.00	111.99	50.71	0.45	0.36	-1.02	82.94
Nigeria	120.77	541.90	219.78	122.70	0.55	1.83	1.96	63.79
Madagascar	65.41	200.00	130.13	40.99	0.31	0.13	-1.28	74.12
Rwanda	79.78	368.81	228.30	87.12	0.38	0.011	-1.29	158.43

Table 1. Summary Statistics of Yearly Producer Prices of Cassava in Major Cassava Markets in Africa ($ Per Ton).

Lag Selection Criteria

Because of sensitivity of time series to lag length and to ensure that errors are white noise in ADF, the information criteria viz. Akaike information criterion (AIC), Hannan–Quinn criterion (HQC) and Schwarz Bayesian criterion (BIC) were used to select appropriate lag length for the analyses. The test results as shown in Table 2 reveals that the optimum lag length appropriate for the specified variables is lag 2 as indicated by the asterisks among the information criteria. This means that the optimum lag length for the series should be lag 2 in order to obtain more interpretable parsimonious models. However, it should be noted that when all the selection criteria agree, the selection is clear, but in situation of conflicting results, the selection criteria with the highest lag order is considered or chosen.

Lag(s)	AIC	BIC	HQC
1	41.06	42.05	41.29
2	40.67*	42.45*	41.09*

Table 2. Lag Selection Criteria.

Unit Root Test

To investigate the market integration, Augmented Dickey Fuller (ADF) test for unit root test was conducted and the results are shown in Table 3. The ADF values of all the series were non-significant at 5 percent level of significance, indicating the existence of unit root in the series; implying non-stationary nature of the data, but at first difference level, the ADF values for all the series were significant at 5 percent level of significance, implying that these price series were free from the consequences of unit root; meaning, the price series were stationary at first difference. ADF-GLS test, which provides an alternate method for correcting serial correlation and heteroscedasticity, was used to validate the results. The results of the unit root test did not reject the null hypothesis of presence of unit root when the series were considered at level. The first differenced series were found to be stationary, i.e., these are integrated of order one. Having ensured I (1) of the price series, the relationship between these markets was estimated using the co-integration test; the conformation that each level series is I (1) allowed to proceed for Johansen's cointegration test.

Market	Stage	ADF		ADF-GLS		Remarks
		T-stat	P < 0.05	T-stat	T-critical (5%)	
Ghana	Level	-0.87	0.9573	-1.17	-3.19	Non-stationary
	1st Difference	-8.10**	8.9E - 013	-6.45**	-3.19	Stationary
Nigeria	Level	-3.31	0.06365	-2.43	-3.19	Non-stationary
	1st Difference	-4.32**	0.01265	-4.47**	-3.19	Stationary
Madgacar	Level	-2.18	0.476	-1.47	-3.19	Non-stationary
	1st Difference	-6.95**	5.466E - 005	-7.31**	-3.19	Stationary
Rwanda	Level	-2.59	0.2838	-2.70	-3.19	Non-stationary
	1st Difference	-4.54**	0.0012	-4.97**	-3.19	Stationary

Table 3. Unit Roots Test with Constant and Trend.

Note: ** indicate that unit root at level or at first difference was rejected at 5 per cent significance.

Johansen's Multiple Co-Integration Test

To determine the long-run relationship between the price series from a range of four price series, Johansen's co-integration test was employed and test revealed only two co-integrating equations for the four selected markets, indicating that there is one stochastic trend present in the system, and also the selected cassava markets had long-run equilibrium relationship. Both tests (Trace and max tests) confirmed that all the selected cassava markets had 2 cointegrating vectors out of 4 cointegrating equations, indicating that they are efficient, well integrated and price signals are transferred from one market to the other to ensure efficiency. Thus, Johnson cointegration test has shown that even though the selected cassava markets in Africa are geographically isolated and spatially segmented, they are well-connected in terms of prices of cassava, demonstrating that the selected cassava markets have long-run price linkage across them (Table 4).

H_0	H_1	Eigen value	Trace test	P-value	Lmax test	P-value
r = 0	r ≥ 1	0.79383	71.277*	0.0001	33.160*	0.0064
r ≤ 1	r ≥ 2	0.66397	38.116*	0.0038	22.902*	0.0256
r ≤ 2	r = 3	0.39967	15.215	0.0536	10.716	0.1716

Table 4. Multiple Cointegration Result.

Note: *denotes rejection of the null hypothesis at 5 per cent level of significance

However, the integration of cassava prices between market pair was tested using Johansen's Cointegration test. Results showed that Ghana market was not cointegrated with Madagascar and Rwanda markets, but cointegrated with Nigeria market despite this market pair where far apart geographically; Nigeria market was cointegrated with Madagascar and Rwanda markets despite being far apart; and, Madagascar market was not cointegrated with Rwanda market (Table 5). Therefore, it could be inferred that cassava markets in pair-wise are to certain extent integrated within Africa.

Market pair	H_0	H_1	Trace test	P-value	Lmax test	P-value	CE
Ghana–Nigeria	r = 0	r ≥ 1	17.724	0.0051	13.204	0.0206	1CE
	r ≤ 1	r ≥ 2	4.5195	0.0381	4.5195	0.0398	
Ghana–Madagascar	r = 0	r ≥ 1	13.198	0.0347	9.893	0.085	NONE
	r ≤ 1	r ≥ 2	3.305	0.0801	3.305	0.082	
Ghana –Rwanda	r = 0	r ≥ 1	13.786	0.0273	8.827	0.130	NONE
	r ≤ 1	r ≥ 2	4.959	0.0292	4.959	0.0308	
Nigeria– Madagascar	r = 0	r ≥ 1	17.941	0.0046	12.390	0.0295	1CE
	r ≤ 1	r ≥ 2	5.551	0.0205	5.551	0.0219	
Nigeria– Rwanda	r = 0	r ≥ 1	19.242	0.0026	14.354	0.0122	1CE
	r ≤ 1	r ≥ 2	4.887	0.0305	4.887	0.0321	
Madagascar–Rwanda	r = 0	r ≥ 1	13.395	0.0320	8.953	0.1237	NONE
	r ≤ 1	r ≥ 2	4.4412	0.0399	4.441	0.0417	

Table 5: Pair-Wise Cointegration.

Note: *denotes rejection of the null hypothesis at 5 per cent level of significance
CE- Cointegration Equation

Vector Error Correction Model

Johansen's test showed there is a long-run association between these markets, thus, justifying the use of a vector error correction model (VECM) to capture the short-run dynamics. The application of VECM indicated estimated coefficients of three markets to be negative and statistically significant (Table 6). The vector error correction (VEC) coefficients were -0.13, -0.74 and -0.21 for Ghana, Nigeria and Madagascar, respectively. This indicates how fast the dependent variables for Ghana, Nigeria and Madagascar markets with respect to prices absorb and adjust themselves for the previous period disequilibrium errors. In other words, the VEC coefficients measure the ability of these markets to incorporate shocks or speculations in the prices. In this case, Ghana, Nigeria and Madagascar markets absorbed 13 percent, 74 percent and 21 percent, respectively to move towards equilibrium in the prices. The information flow was more in Ghana market as is evident from the magnitude of the VEC coefficient (0.13). In other words, the prices of cassava in Ghana, Nigeria and Madagascar markets are sensitive to departure from their equilibrium states or levels in the previous periods. For Ghana, Nigeria and Madagascar markets, the slope coefficients of the error correction term are 0.13; 0.74; 0.21 respectively, representing the speed of adjustment, and also consistent with the hypotheses of convergence towards the long-run equilibrium once the price equations are disturbed. This means that, it will take Ghana, Nigeria and Madagascar markets about 1 months 17 days; 8 months 26 days and 2 months 16 days respectively, to adjust fully to equilibrium position in the long run due to disturbances in the marketing system in the study area i.e these markets are above the equilibrium and it will take approximately 1months 17 days; 8 months 26 days and 2 months 16 days in Ghana, Nigeria and Madagascar markets respectively, to correct equilibrium errors. The empirical results revealed that, the long run models of cassava prices for Ghana, Nigeria and Madagascar markets in Africa converges to the postulate of the law of one price. The constant terms in the three long run equations give the picture of the transfer cost or the extent of price differential which are due to arbitrage activities. Results further revealed insignificant influence of the transfer cost in the marketing process of cassava in Rwanda market, perhaps suggesting high efficiency in information transmission between Rwanda market and other markets, and improvement in the marketing infrastructures in Rwanda market. However, the coefficient of Vector Error correction term for Rwanda market was negative but non-significant.

The effects of lagged prices in the selected markets were negative as well as positive, suggesting that, in the short-run, price shocks were contemporaneously transmitted in these markets but not fully. In Ghana market, its own lagged prices and lagged prices in Nigeria market tends to affect it; in Nigeria market, its own lagged prices and lagged prices of Madagascar market tends to affect it; in Madagascar market, lagged prices of Nigeria market and its own lagged prices tends to affect it; and in Rwanda market, only lagged prices of Ghana market affect it. In other words, the short-run dynamics indicates that one year lagged prices in Ghana and Nigeria markets were transmitted to current prices in Ghana market; one year lagged prices in Nigeria and Madagascar markets were transmitted to current prices in Nigeria market; one year lagged prices in Nigeria and Madagascar markets were transmitted to current prices in Madagascar market; and one year lagged prices in Ghana market was transmitted to current prices in Rwanda market. To strength the linkage and interconnectedness among these selected markets for faster transmission of price and management of commodity from surplus area to deficit area, the clarion call is to enhance the development of market infrastructure, use of information and technology in transaction of goods (COMEXB), processing, transportation and other back-end supply chain of cassava. This would definitely help in the development of single integrated economic market for cassava in Africa.

Variable	D(Ghana)	D(Nigeria)	D(Madagascar)	D(Rwanda)
ECT	-0.1296	-0.7399	-0.2089	0.0615
	(0.0496)	(0.2312)	(0.054)	(0.1510)
	{-2.609}**	{-3.200}***	{-3.852}***	{0.407}NS
D(Ghana)	0.378	0.389	0.1814	-1.204
	(0.2086)	(0.972)	(0.0728)	(0.6346)
	{1.813}*	{0.401}NS	{0.796}NS	{-1.897}*
D(Nigeria)	0.175	0.688	0.2648	0.3147
	(0.0667)	(0.311)	(0.0728)	(0.2028)
	{2.619}**	{2.214}**	{3.637}***	{1.552}NS
D(Madagascar)	-0.274	-2.076	-0.8069	-0.783
	(0.1690)	(0.787)	(0.1846)	(0.514)
	{-1.619}NS	{-2.637}**	{-4.371}***	{-1.522}NS
D(Rwanda)	0.084	-0.0075	-0.0701	0.1943
	(0.1054)	(0.491)	(0.1151)	(0.3204)
	(0.799)NS	{-0.015}NS	{-0.6091}NS	{0.6063}NS
Constant	26.22{2.817}***	148.64{3.429}***	-28.56{-2.81}**	21.277{0.7515}NS

Table 6: Vector Error Correction Model of major cassava markets in Africa.
Note: *** ** * implies significance at 1%, 5% and 10% respectively
NS: Non-significant
(); {} implies Standard error and t-statistic

Granger Causality Test

After determining cointegration among different cassava markets, granger causality was also estimated between the selected pairs of cassava markets in Africa. 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 prices difference. Results of granger causality tests showed that all the three F-statistics for the causality tests of producer's prices in Nigeria market on other markets were not statistically significant, thus, the null hypothesis of no granger causality was accepted in each case for Nigeria market. Besides, Madagascar market had two, while Ghana and Rwanda markets each had one F-statistics statistically significant on other market prices (Table 7).

According to the granger causality tests, there were unidirectional causalities between these market pairs: Rwanda-Nigeria, Ghana-Rwanda; Madagascar-Nigeria and Madagascar-Rwanda markets, meaning that a price change in the former market in each pair granger causes the price formation in the latter market, whereas the price change in the latter market is not feed backed by the price change in the former market in each pair. However, bi-directional causality was not observed, thus, indicating there is no perfect price transmission mechanism between any cassava market pair. Further, two market pairs, Ghana-Nigeria and Madagascar-Ghana have no direct causality between them, indicating that neither the former in each market pair granger causes the price formation in latter, nor the latter in each market pair granger causes the price formation in the former. In other words, there is no long-run price association between these market pairs.

H_0	T-stat	Prob.	Granger cause	Direction
Ghana → Nigeria	0.754	0.490	No	**None**
Ghana ← Nigeria	0.098	0.907	No	
Madagascar → Ghana	0.284	0.757	No	**None**
Madagascar ← Ghana	0.486	0.626	No	
Nigeria → Rwanda	0.961	0.408	No	**Unidirectional**
Nigeria ← Rwanda	7.769	0.006**	Yes	
Rwanda → Ghana	1.999	0.175	No	**Unidirectional**
Rwanda ← Ghana	6.103	0.014**	Yes	
Madagascar → Nigeria	4.296	0.037**	Yes	**Unidirectional**
Madagascar ← Nigeria	2.460	0.124	No	
Rwanda → Madagascar	1.196	0.333	No	**Unidirectional**
Rwanda ← Madagascar	11.145	0.005**	Yes	

Table 7: Pair Wise Granger Causality Tests of Selected Markets.

Note: **denotes rejection of the null hypothesis at 5 per cent level of significance

VECM Diagnostic checking

Autocorrelation tests for all the selected markets indicate that the residuals are free from serial correlation as evident from Ljung-Box Q-statistics which are not different from zero at 5 percent probability level, meaning that the residuals are purely random. Also, the Arch effects indicates that the error term have no arch effects as evidence from the LM test statistics which are not different from zero at 5 percent probability level. The tests of normality indicate that the residuals are normally distributed as evidence from Doornik-Hansen test which is not different from zero at 5 percent probability level.

Therefore, it can be inferred that the model used certified all the necessary criteria for it to be term best fit.

Test		Statistic	P-value
Autocorrelation	Ljung-Box Q (Eq1)	4.872	0.0875
	Ljung-Box Q (Eq2)	0.761	0.684
	Ljung-Box Q (Eq3)	0.274	0.872
	Ljung-Box Q (Eq4)	0.168	0.92
Arch effect	LM-Test (Eq1)	2.594	0.273
	LM-Test (Eq2)	3.256	0.196
	LM-Test (Eq3)	1.452	0.484
	LM-Test (Eq4)	0.517	0.772
Normality	Doornik-Hansen test	11.038	0.1996

Table 8: VECM Diagnostic checking.

Impulse Response Functions

The results of impulse response functions show how and to what extent a standard deviation shock in one of the cassava markets affects the current as well as future prices in all the integrated markets over a period of ten years. When the effect of a shock dies out over time, the shock is said to be transitory and when the effect of a shock does not die out over time, the shock is said to be permanent. It can be observed that when a standard deviation shock is given to any market, the effects on other markets will either be permanent or transitory i.e the responses of other markets appear or disappear between second and tenth years.

The graphs indicate that an orthogonalized shock to the prices in Ghana market will have permanent effect on the prices in Rwanda market and transitory effects on the prices in Nigeria and Madagascar markets; while an orthogonalized shock to the prices of cassava in Nigeria market will exert transitory effects on Ghana and Madagascar markets, and a permanent on the price in Rwanda market. According to this model, unexpected shock that are local to Madagascar market will have permanent effects on the prices in Ghana and Nigeria markets, and a transitory effect on Rwanda market; while unexpected shock that are local to Rwanda market will have only permanent effects on the prices in Ghana, Nigeria and Madagascar markets. A shock originating from the Ghana market is less transmitted to Nigeria and Madagascar markets, and more transmitted to Rwanda market, but a shock originating from Nigeria and Madagascar market are relatively less transmitted to Ghana market, and relatively more transmitted to Ghana market if the shock originates from Rwanda market. Like Ghana market, a shock given to the Nigeria market is transmitted to a lesser extent to other markets except Rwanda market, implying that Ghana and Nigeria markets are relatively market followers and do not play a significant role in international cassava markets of Africa. An important point to be noted is that the producer prices in the Madagascar market is positively related to prices in Ghana and Nigeria markets and inversely related to the prices in the Rwanda market. On the other hand, the results of Rwanda market impulse response confirm that the price transmission from Rwanda to other markets occur in large proportions, thus, implying that the Rwanda market has dominance in price determination in other cassava markets (Figure 1).

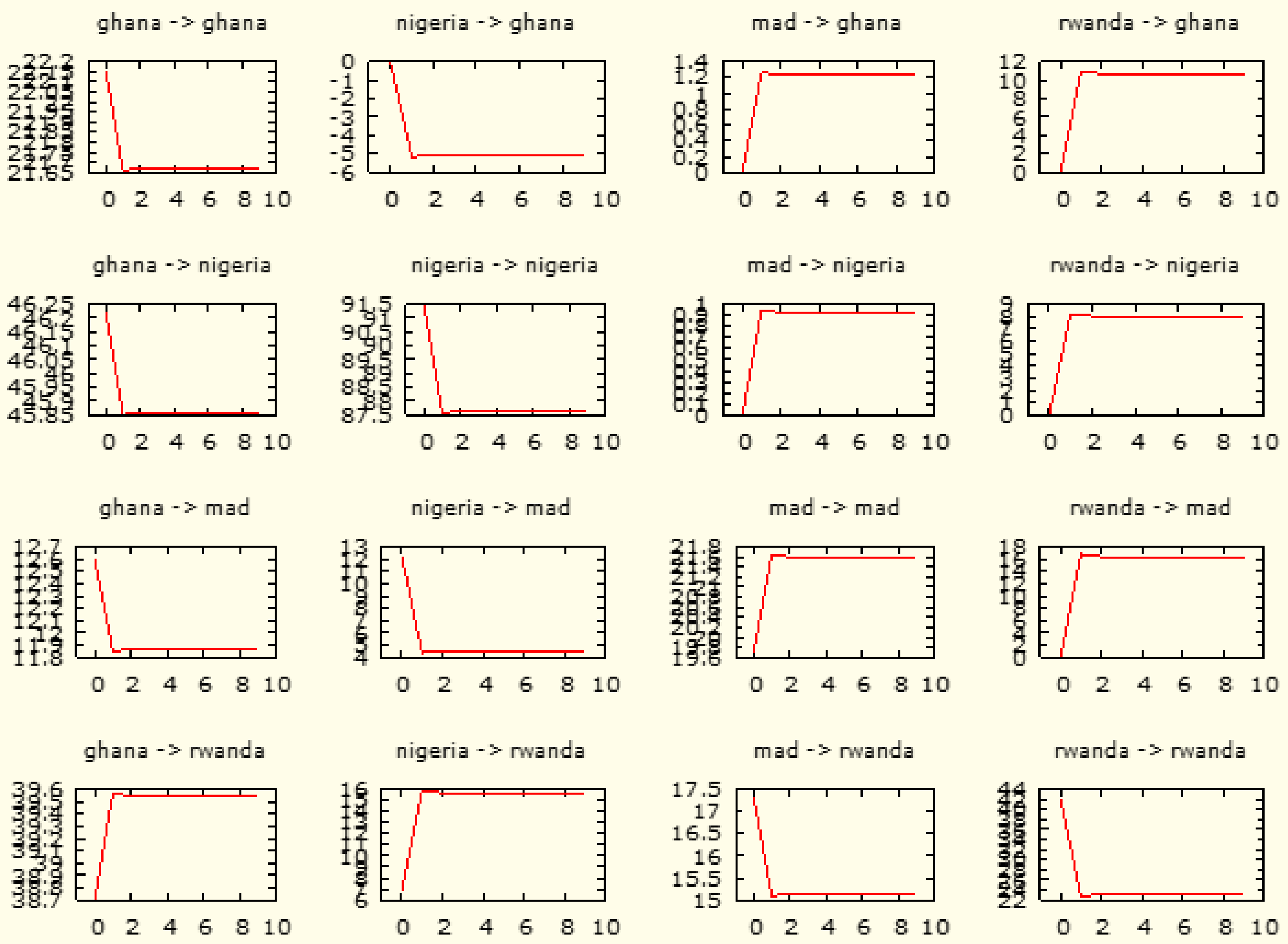


Figure 1: Impulse Response Functions.

Extent of Price Volatility in cassava markets

The results of GARCH model have indicated that GARCH order (1,1) fit different markets and was found to be the highest order for the entire period (Table 9). Results further indicated that, the estimated sum coefficients of alpha and beta for all the markets were closer to unity, indicating the persistence of volatility in cassava prices of selected markets. The results of GARCH analyses indicated that volatility in the current year prices in all the selected markets depends on information about volatility in the preceding year prices, which are evidence from the significance ARCH-terms. For the entire period, volatility in the current year prices in all the selected markets were not influenced by volatility in prices during the preceding year, as evidence from non-significance GARCH terms. As expected, none of the series showed an 'explosive' pattern as the values of ($\alpha_i + \beta_i$) did not exceed one, which infers the usefulness of cassava trading in Africa. The reason for persistence of volatility in prices in all the selected markets could be due to nascent stage of cassava marketing at international level.

Particulars	Ghana market	Nigeria market	Madagascar market	Rwanda market
Family shocks				
Constant	98.15(1.13E-038)***	-	-	-
Alpha (0)	227.59(0.562)^{NS}	12836.8(1.43)^{NS}	2435.97(1.495)^{NS}	15471.5(2.399)**
Alpha (1)	0.61(1.68)*	0.874(2.092)**	0.787(3.187)***	0.825(3.305)***
Beta (1)	0.37(0.996)^{NS}	1.55E-012(1.009E-011)^{NS}	0.141(0.681)^{NS}	5.07E-011(1.00)^{NS}
Log likelihood	-123.83	-163.39	-150.95	-164.59
GARCH fit	1,1	1,1	1,1	1,1
$\alpha + \beta$	0.98	0.874	0.928	0.825

Table 9: Estimates of GARCH Model for Measuring Volatility in Prices of Cassava from 1991-2014.
Notes: Figures within the parentheses indicate the calculated t-statistic
*** ** and * indicate the significance at 1%, 5% and 10% probability levels respectively
NS: Non-significant

GARCH Diagnostic checking

Autocorrelation tests for all the selected markets indicate that the residuals are purely random as evidence from the Q-statistics which are not different from zero at 5 percent probability level. Tests of normality for all the selected markets indicate that the residuals are not normally distributed as evidence from the chi2 which are different from zero at 5 percent probability level (Table 10). However, normality test is not considered a serious matter because in most cases data are not normally distributed.

Model	Market	ARCH-LM Test	Normality Test (Chi^2)
GARCH	Ghana	0.7433 (0.989)	2.81 (0.000)
	Nigeria	0.5809 (0.559)	43.7 (0.000)
	Madagascar	0.5312 (0.943)	3.06 (0.002)
	Rwanda	0.3836 (0.180)	2.73 (0.000)

Table 10: Diagnostic Checking for GARCH.
Note: Values in parentheses are probability

Forecasting Using ARIMA

Various combinations of the ARIMA models were tried after first differencing of all the four series and based on the smallest AIC value; the best ARIMA model was selected. Among all the ARIMA models tested, ARIMA (0,1,1) model have the minimum AIC values for price series of Ghana; Nigeria and Rwanda markets, while ARIMA (1,1, 0) model has minimum AIC value for Madagascar market price series (Table 11a).

Market	Criteria	1,1,1	1,1,0	0,1,1
Ghana	AIC	213.8948	217.6009	211.9551**
	BSC	218.4367	221.0074	215.3616
Nigeria	AIC	286.3866	284.3922	284.3897**
	BSC	290.9286	287.7987	287.7962
Madagascar	AIC	229.0783	227.0941**	227.8623
	BSC	233.6203	230.5006	231.2688
Rwanda	AIC	261.8691	261.0318	260.9208**
	BSC	265.2755	260.3028	263.1918

Table 11a: AIC values of different ARIMA models.
Note:**denotes best ARIMA model

Out of total 23 data points (1991 to 2014), first 18 data points (from 1991 to 2009) were used for model building and the remaining 5 data points (from 2010 to 2014) were used for model validation. One-step ahead forecasts of producer prices for all the selected markets along with their corresponding standard errors using naïve approach for the period 2009 to 2014 (total 5 data points) in respect of above fitted models were computed (Table 11b).

Date	Ghana market		Nigeria market		Madagascar market		Rwanda market	
	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast
2010	168.95	156.58	142.45	113.93	172.44	184.65	312.27	314.33
2011	176.96	170.58	142.91	141.63	168.08	178.11	265.85	312.53
2012	184.00	183.89	152.55	141.24	170.00	174.94	297.21	271.84
2013	196.00	191.22	161.68	151.19	179.00	174.31	368.81	293.95
2014	210.00	201.70	171.00	160.30	200.00	180.44	337.23	359.20

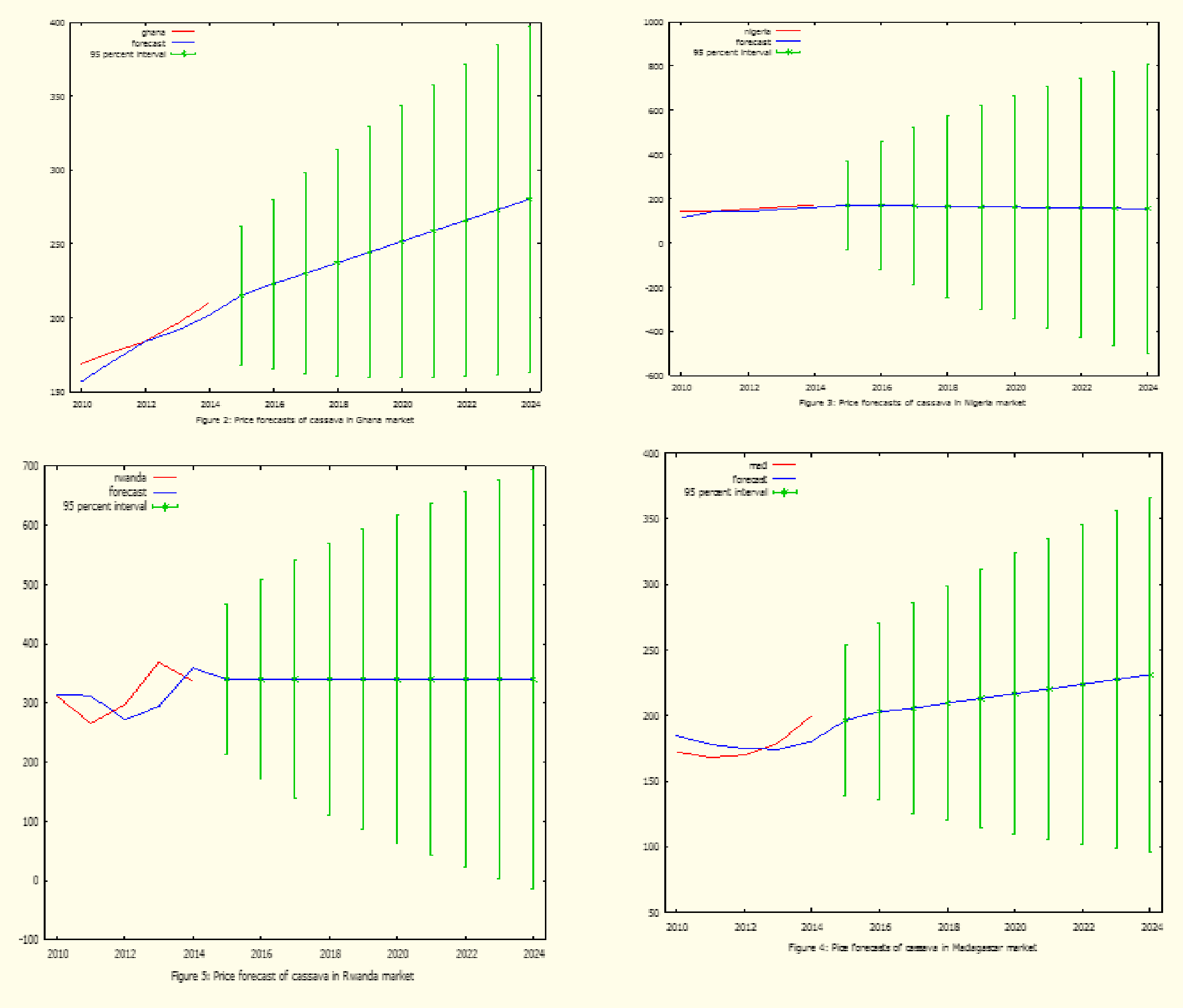
Table 11b: One Step Ahead Forecast of Prices.

The forecasting ability of ARIMA (0,1,1) models of price series for Ghana, Nigeria and Rwanda markets; and forecasting capability of ARIMA (1,0,1) model for Madagascar market price series were judged on the basis of mean absolute prediction error (MAPE), relative mean absolute prediction error (RMAPE) and root mean square error (RMSE) values (Table 11c). A perusal of Table 11c reveals that for all the price series for all the selected market, RMAPE values were less than 10 percent, indicating the accuracy of the models used in the study.

Market	MAPE	RMSPE	RMAPE (%)
Ghana	6.388	0.31608	3.48
Nigeria	12.46	1.582	8.22
Madagascar	0.586	0.729	0.711
Rwanda	5.904	5.4004	0.820

Table 11c: Validation of Models.

One step ahead out of sample forecast of producer price of cassava for the above four markets during the periods 2015 to 2024 were computed. The forecast values along with their corresponding lower and upper 95 per cent confidence intervals are given in (Table 11d). As indicated, cassava prices in Nigeria and Rwanda markets will be volatile during the periods 2014 to 2024, as reflected by the wider confidence intervals associated with the ARIMA forecasts during this period. These imply that the confidence intervals associated with the one-step-ahead out of sample forecasts during this period are relatively large. Alternatively, while the confidence intervals of cassava price forecasts for Ghana and Madagascar markets do fluctuate, they tend to be more stable relative to the forecasts intervals for Nigeria and Rwanda markets. These imply the confidence intervals associated with the one-step ahead out of sample forecasts during these periods are relatively smaller. This, in part, might reflect the relatively constant growth of the cassava production during the period 2015 to 2024. The fitted models along with the predicted data points are also depicted in figure 2 to visualize the performance of fitted models.



Row 1: Graph 1-Ghana market, Graph 2-Nigeria market.
Row 2: Graph 3-Madagascar market, Graph 4-Rwanda market.
NS: Non-significant

Year	Ghana market			Nigeria market		
	Forecast	Upper CL	Lower CL	Forecast	Upper CL	Lower CL
2015	215.08	262.16	168.00	169.62	371.15	102.82
2016	222.91	280.18	165.64	167.91	457.39	147.69
2017	229.89	298.11	161.68	166.20	522.54	121.81
2018	237.13	314.12	160.15	164.49	576.99	110.47
2019	244.29	329.33	159.26	162.78	624.67	135.66
2020	251.48	343.81	159.15	161.07	667.55	158.41
2021	258.66	357.77	159.55	159.36	706.81	129.32
2022	265.84	371.29	160.39	157.65	743.21	128.76
2023	273.02	384.45	161.59	155.94	777.28	117.02
2024	280.20	397.30	163.10	154.23	809.40	134.28
Year	Madagascar market			Rwanda market		
	Forecast	Upper CL	Lower CL	Forecast	Upper CL	Lower CL
2015	196.57	254.34	138.80	340.05	466.38	213.72
2016	203.05	270.25	135.85	340.05	507.63	172.47
2017	205.51	285.75	125.28	340.05	540.56	139.54
2018	209.60	299.25	119.96	340.05	568.81	111.29
2019	213.03	311.84	114.23	340.05	593.93	129.53
2020	216.73	323.67	109.79	340.05	616.78	141.19
2021	220.32	334.91	105.73	340.05	637.88	151.96
2022	223.96	345.68	102.23	340.05	657.58	162.01
2023	227.57	356.05	99.09	340.05	676.13	171.47
2024	231.19	366.08	96.31	340.05	693.71	180.44

Table 11d: Out of Sample Forecast of Cassava Prices in Selected Markets.
Note: CL- Confidence Level

ARIMA 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 chosen ARIMA. Results of autocorrelation tests for all the selected markets indicate that the residuals are purely random as evidence from the Ljung-Box Q-statistics which are not significantly different from zero at 5 percent probability level (Table 12).

This proved that the selected ARIMA (0,1,1) model for price series of Ghana, Nigeria and Rwanda markets; and ARIMA (1,1,0) model for Madagascar market were appropriate model for forecasting. Also, the Arch effect tests showed no arch effects in the residuals as evidence from Lagrange multiplier test which is not different from zero at 5 percent probability level. The normality tests for all the selected markets indicate that the residuals are not normally distributed as evidence from the Chi2 values which are significantly different from zero at 5 percent probability level (Table 12). However, normality test is not considered a serious matter because in most cases data are not normally distributed. Therefore, the selected models were the best fit.

Market	ARIMA model	Autocorrelation test (Ljung-Box Q)	Arch test (LM)	Normality Test (Chi^2)
Ghana	0,1,1	2.577(0.108)	2.939 (0.230)	0.414 (0.000)
Nigeria	0,1,1	0.0993 (0.753)	0.451(0.798)	13.16 (0.0014)
Madagascar	1,1,0	0.0358 (0.850)	4.715 (0.095)	2.895 (0.000)
Rwanda	0,1,1	2.982 (0.084)	2.702 (0.259)	6.511(0.038)

Table 12: Diagnostic Checking for Best ARIMA Models.

Conclusions and Recommendations

The study investigated cointegration, causality, price transmission, price volatility and price forecast among major cassava markets in Africa. ADF tests results indicated that all the price series were integrated of order 1. Results of multiple cointegration test indicated that different cassava markets in Africa are well-integrated and have long-run price association across them. The market pair-wise cointegration test confirmed that all the market pairs do not have any price association between them, indicating that the major cassava markets in Africa are poor integrated when considered pair-wise. Some inferences were drawn from the market integration: Price transmission occurs due to the flow of market information which is a consequence of development in information technologies; the speed of convergence depends on the market regulations and policy changes; and market integration is an indicator of efficient functioning of markets. VECM results indicate that Ghana, Nigeria and Madagascar markets were above the equilibrium, and it will take approximately 1months 17 days; 8 months 26 days and 2 months 16 days respectively to correct their respective equilibrium error. Also, Granger causality tests showed only four market pairs had unidirectional causalities, while all the remaining market pairs had no causal direction on price formation between them. Situation of market pair bidirectional causality was not observed between the major cassava markets in Africa. Further, results of impulse response functions confirmed that the speeds as well as magnitude of shocks given to Ghana and Nigeria markets are relatively less transmitted to other markets, thus indicating these markets to be trend followers and not trend setters. This implies that the geographical situation and optimal distance between the market places hold the mutual forces on commodity movements and price formation. Therefore, the researchers advocate that the network of agricultural producer markets should be well-designed so as to keep equal distance from each other, because it will not only boost a direct inter-market competition, but will also control the massive/high marketing margins of agricultural commodities. The produce can be moved to the deficit areas thereby providing benefits to both producers and consumers. The extent of volatility in current prices due to family or internal shocks, as measured by the coefficients of GARCH model, indicated persistence volatility in all the markets, but not of the explosive type, thus indicating usefulness of cassava trading in Africa. Lastly, findings revealed that the ARIMA model could be used successfully for modelling as well as forecasting of yearly producer price of cassava in major cassava markets in Africa, given that the model has demonstrated a good performance in terms of explained variability and predicting power. Findings of the present study will serve as direct support for the potential use of accurate forecasts in decision-making for farmers, middlemen as well as consumers.

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