Econometric Analysis of the Effects of Land Size on Cereals Production in Nigeria

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Abstract
*This study employed the techniques of unrestricted VAR to model and analyzed the causal effects of Land used for Cereals Production (LP) on Cereals Production (CP) in Nigeria for the period of 50 years (1966 to 2016). The data extracted from the repository of World Bank were used to obtain the time plots which depicted that the CP and LP series are not stationary at level. The unit root and cointegration tests carried out suggested that the series are integrated of order one I (1) and that the series are not co-integrated. This confirmed that the use of VAR(p) model was appropriate for analyzing the data. Based on the LR, FPE and AIC selection criteria, VAR (2) model was fitted to the data. Results from the fitted model estimates showed that both CP and LP series in immediate past periods **t-1** (2015) and two previous periods **t-2** (2014 and 2015) have significant impacts on CP series in current time period **t** (2016) while only LP in immediate past period **t-1** (2015) has a significant effect on LP in current time period **t** (2016). The results of Granger causality test indicate a unidirectional relationship which runs from LP to CP. It is recommended that the Federal Government of Nigeria should re-visit the land tenure system policies and embrace those that will enhance easy acquisition of land by farmers for more cereals production.*

Keywords: Cereals Production; Unrestricted VAR; Granger Causality; Cointegration; Nigeria.

Introduction

Quantity of most agricultural produce is determined by the size of cultivated land in that the larger the land size, the higher the farm produce, *ceteris paribus*. Specifically, land size plays a vital role in the quantity of cereals production in Nigeria in particular and Africa by extension. In Africa, cereals production has increased by 125% and cultivated land by 70% in the last 30 years (NEPAD, 2013). In Nigeria, cereal production has increased from 6,140,000 metric tons in 1966 to 25,035,578 metric tons in 2016 which represents 76% increment while land under cereal production has increased from 10,102,000 ha in 1966 to 17,342,468 ha in 2016 depicting 42% increment (World Bank, 2018). The major cereal crops in Nigeria are rice, maize, sorghum, wheat, pearl millet, sugar cane and fonio millet with rice ranking as the sixth major crop in terms of the land area while sorghum accounts for 50% of the total cereals production and occupies about 45% of the total land area devoted to Nigerian cereals production (NEARLS, 1996). Statistics shown that the most consumed cereal crop in Nigeria is rice. According to FAO (2019), Nigeria is the leading consumer of rice in Africa continent, one of the largest producers of rice in Africa and simultaneously one of the largest rice importers in the world. However, the Federal Government of Nigeria implemented a policy to efficiently control importation of goods. This led to the closure of Nigeria's borders very recently (in August, 2019). The essence of this closure is to prevent importation and encourage citizens to concentrate on local production.

Sorghum is the second cereal in terms of quantity of production in Nigeria, with more than 4.5 million tons harvested in 2010 representing 25% of the total cereals production and the country is the third largest world producer of sorghum after the United States and India (FAOSTAT, 2012). Essentially, Nigeria is the largest sorghum producer in West Africa, accounting for about 71% of the total regional sorghum production (Ogbonna, 2011). Wheat farming has been the most complicated area of Nigerian agriculture for the last decade, owing to high temperatures unsuitable for the crop. As a result, Nigeria has depended on imported wheat to meet the growing demands of her large population. Even in all African countries, wheat consumption has been steadily increasing during the past two decades as a result of growing population, changing food preferences and a strong urbanization trend which has led to a growing 'food gap' in all regions, largely met by imports (FAO, 2017). Nigeria has become increasingly important in the production of pearl millet even with the numerous problems involved in its cultivation. Nigeria has moved from the third to the present second largest producer in the world (Aminu *et al.*, 1998). Nigeria also has land potential of over 500,000 hectares of suitable cane fields that can produce over 5 million metric tons of sugarcane that when processed, can yield about 3 million metric tons of sugar. However, the sector has been neglected and the nation now depends almost totally on refining imported raw brown sugar from Brazil worth over 500 million US dollars (NSDC, 2003). A common feature of past published works on cereals was either based on univariate time series models or other statistical techniques. In this study, multivariate time series approach known as Vector Autoregressive (VAR) model was used to model and analyze the causal effect of land size on cereals production.

Literature Reviews

Several studies have been conducted on cereals in the recent years. For instance, Badmus and Ariyo (2011) forecasted cultivated areas and maize production in Nigeria using univariate time series approach known as ARIMA model. Shabu and Terfa (2011) applied Cobb-Douglas production function and technical efficiency techniques to analyze efficiency of resources used in rice farming enterprise in Kwande Local Government Area of Benue State, Nigeria. To access the progress made so far on cereal production in Nigeria, Akanni (2019) forecasted the cereals production using ARIMA (1, 1, 1) model. Maikasuwa and Ala (2013) applied trend analysis to study the area and productivity of sorghum in Sokoto State of Nigeria. The results of the trend analysis later revealed a stagnated growth in area and an accelerated growth in productivity. This study, however, focused on examining the direction of causality between cereals production (CP) and Land used for cereals production (LP) in Nigeria.

Materials and Methods

In carrying out this study, an annual time series data on cereals production (CP) and land under cereal production (LP) in Nigeria covering 1966 to 2016 was extracted from the repository of World Bank via their website http://data.worldbank.org. This study utilized the Vector Autoregressive (VAR) model developed by Sims (1980) to analyze the causal effect of land size on cereal production in Nigeria. The VAR approach sidesteps the need for structural modeling by treating every endogenous variable in the system as a function of the lagged values of all of the endogenous variables in the system.

The mathematical representation of a VAR (p) model is of the form:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + \dots + A_p y_{t-p} + Bx_t + e_t \qquad (1)$$

where: $\mathbf{y_t}$ is a k vector of endogenous variables, $\mathbf{x_t}$ is a d vector of exogenous variables, $\mathbf{A_1}$ to $\mathbf{A_p}$ and **B** are matrices of coefficients to be estimated, $\mathbf{e_t}$ is a vector of innovations that may be contemporaneously but are uncorrelated with their own lagged values and uncorrelated to all of the right hand side variables.

Model Specification for CP and LP Series

The bivariate Vector Autoregressive model of order two {VAR (2)} for cereal production (CP) and land under cereal production (LP) series is given by:

$$\mathrm{CP_t} = \alpha_{11}\mathrm{CP_{t-1}} + \alpha_{12}\mathrm{CP_{t-2}} + b_{11}\mathrm{LP_{t-1}} + b_{12}\mathrm{LP_{t-2}} + c_{11} + e_{1t} \qquad (2)$$

$$\mathrm{LP_t} = \alpha_{21}\mathrm{CP_{t-1}} + \alpha_{22}\mathrm{CP_{t-2}} + b_{21}\mathrm{LP_{t-1}} + b_{22}\mathrm{LP_{t-2}} + c_{22} + e_{2t} \qquad (3)$$

In order to achieve the goal of the study, the following six basic steps of VAR were followed:

Unit Root Analysis

The unit root analyses were conducted for CP and LP series individually using the Augmented Dickey-Fuller (ADF) method with drift in each case. The essence of this was to check if these series are integrated of order one {I(1)} or not. If they are I(1), we therefore progress to cointegration testing. Otherwise we result to other models. Equations (4) and (5) below represent the ADF equations for CP and LP series respectively.

$$\Delta\mathrm{CP_t} = \beta_1 + \delta\mathrm{CP_{t-1}} + \mathrm{u_t} \qquad (4)$$

$$\Delta\mathrm{LP_t} = \beta_1 + \delta\mathrm{LP_{t-1}} + \mathrm{u_t} \qquad (5)$$

where:$\delta = \rho - 1$, β_1 = drift or intercept term, t = trend or time, u_t = white noise, CP_t and LP_t are random walks ,CP_{t-1} and LP_{t-1} are the lagged one periods of the CP and LP time series variables.

Hypothesis for equation (4): $H_0: \delta = 0$ (CP has a unit root) *versus* H_1: Not H_0
Hypothesis for equation (5): $H_0: \delta = 0$ (LP has a unit root) *versus* H_1: Not H_0
The test statistic is given by $t_\alpha = \frac{\hat{\alpha}}{SE(\hat{\alpha})}$ (6)
The decision rule is to reject the null hypothesis if computed value of t_α is greater than the critical value at 5% significance level. Otherwise, the null hypothesis will not be rejected. Alternatively, the associated p-value would be compared with the significance level and the null hypothesis will be rejected if obtained p-value is less than the significance level.

Cointegration Testing
Once the series are confirmed to be I(1), the next thing was to find out if there exists cointegration between these series. If the I(1) variables in the system satisfy conditions of cointegration relations, then the system will be appropriately specified as a vector error correction model (VECM) otherwise we use VAR system (Engle and Granger; 1987). Here we performed the cointegration test using Johansen (1991, 1995) approach by re-stating equation (1) as equations (8) and (9) as follow:
$\Delta y_t = \pi y_{t-i} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + e_t$ (8)
Where: $\boldsymbol{\pi} = \sum_{i=1}^{p} A_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$ (9)
Granger's representation theorem asserts that if the coefficient matrix $\boldsymbol{\pi}$ has reduced rank **r** < **k**, then there exist **k** by **r** matrices $\boldsymbol{\alpha}$ and β each with rank **r** such that $\boldsymbol{\pi = \alpha\beta'}$ **and** $\boldsymbol{\beta' y_t}$ **is** I(0), **r** is the number of cointegrating relations (the cointegrating rank) and each column of **β** is the cointegrating vector.

VAR Optimal Lag Order, Estimation of the Appropriate VAR Model, Granger Causality Tests on the VAR Model and Response Graphs
Having found the appropriate model to be VAR (p) model, it is therefore imperative to determine the maximum lag terms to be included in each equation of the VAR system. Selection criteria like Sequential modified likelihood ratio test statistic (LR), Final Prediction Error (FPE), Akaike Information Criteria (AIC), Schwarz Information Criteria (SIC) and Hannan-Quinn Information Criteria (HQ) were used to determine the best VAR model. The VAR model is estimated based on the determined optimal lagged terms. We checked if there is connection between VAR and causality. Finally, the impulse response function graph is plotted to check if the time series variable is sensitive to each other or not.

Data Analysis and Results
The analyses of the time series data for CP and LP were carried out using Eviews 9.0 Statistical Package and the results are presented as follows

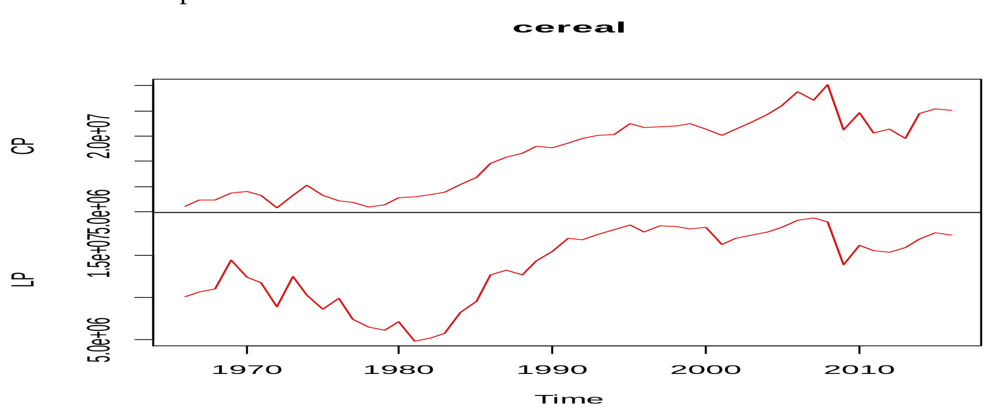

Figure 1: Time plots of Cereals Production (CP) and Land under Cereal Production (LP) series

Figure 1 shows that both the CP and LP series exhibit upward trends albeit with fluctuations. This means that these series are not stationary level series. That is, they have to be differenced once or twice in order to attain stationarity. The results reported by the Time plots are further confirmed by subjecting these series to unit root test conducted on the CP and LP series as shown in Table 1.

Table 1: Results of ADF Test for CP and LP Series

Test Variable	ADF Statistics	Critical values	P-value	Order of Integration
CP	-4.1865	-2.9238	0.0018	I(1)
LP	-8.1516	-2.9224	<0.0001	I(1)

From Table 1, ADF test results for CP series shows that the series is stationary at first difference with the value of ADF statistic (= -4.1865) which is less than the critical value (= -2.9238) obtainable from the statistical tables. The p-value (= 0.0018) is also significant since it is less than the chosen level of significance (α= 0.05). Also, , ADF test results for LP series indicate that the series is stationary at first difference with the value of ADF statistic (=8.1516) which is also less than the critical value (=-2.9224) obtained from the statistical tables. And the p-value (< 0.0001) is also significant since it is less than the level of significance (α= 0.05). This made the null hypothesis of non-stationarity to be rejected in both cases. Having found that the CP and LP series to be I(1), the system will therefore be subjected to cointegration tests to decide whether the VAR or VECM model will be appropriate for modeling the series. Table 2 gives the results of cointegration tests conducted on the series.

Table 2: Cointegration Test Results

Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**Critical Value at 5%**	**P-Value**
None	0.067542	4.249613	15.49471	0.8824
At most 1	0.016655	0.822965	3.841466	0.3643
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	Critical Value at 5%	P-Value
None	0.067542	3.426648	14.26460	0.9143
At most 1	0.016655	0.822965	3.841466	0.3643

From Table 2, both the trace and maximum eigenvalue test results indicate no co-integration. This means that there is no long-run relationship between the CP and LP series. Hence, the VAR model is appropriate for the series since there is no evidence of cointegration relationship between these two series (Engle and Granger; 1987).

Table 3: Lag Selection Criteria

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**
0	-1551.048	NA	1.72e+26	66.08714	66.16587
1	-1469.957	151.8292	6.48e+24	62.80669	**63.04288***
2	-1462.645	**13.06859***	**5.64e+24***	**62.66575***	63.05940
3	-1459.404	5.516400	5.84e+24	62.69805	63.24916
4	-1456.580	4.566653	6.17e+24	62.74809	63.45665

** indicates lag order selected by the criterion*

From Table 3, the least value of the selection criteria LR, FPE and AIC occurs at lag 2. Hence, VAR of lag 2 is the appropriate model for analyzing the CP and LP series.

Table 4: VAR (2) Model Estimates

	CP	**LP**
CP(-1)	0.370901 (0.17767) [2.08758]	-0.142190 (0.14738) [-0.96476]
CP(-2)	0.617960 (0.17417)	0.228627 (0.14448)

	[3.54812]	[1.58246]
LP(-1)	0.545785 (0.23464) [2.32605]	0.894099 (0.19464) [4.59356]
LP(-2)	-0.585195 (0.23350) [-2.50621]	-0.080153 (0.19369) [-0.41381]
C	1239625 (992225) [1.24934]	1349291 (823083) [1.63931]
R^2	0.936705	0.881878

From Table 4, the estimated VAR (2) model are stated as equations (11) and (12)

$$CP_t = 0.370901CP_{t-1} + 0.228627CP_{t-2} + 0.545785LP_{t-1} - 0.585195LP_{t-2} + 1239625 \quad (11)$$

$$LP_t = -0.142190CP_{t-1} + 0.0000789CP_{t-2} + 0.894099LP_{t-1} - 0.080153LP_{t-2} + 1349291 \quad (12)$$

Table 5: System of VAR Equations

	Coefficient	Std. Error	t-statistic	P-value
C(1)	0.370901	0.177670	2.087580	**0.0397**
C(2)	0.617960	0.174165	3.548124	**0.0006**
C(3)	0.545784	0.234641	2.326045	**0.0223**
C(4)	-0.585195	0.233498	-2.506211	**0.0140**
C(5)	1239625	992225.1	1.249339	0.2149
C(6)	-0.142190	0.147383	-0.964761	0.3373
C(7)	0.228627	0.144476	1.582460	0.1171
C(8)	0.894099	0.194642	4.593555	**<0.0001**
C(9)	-0.080153	0.193694	-0.413813	0.6800
C(10)	1349291	823083.1	1.639314	0.1047
Determinant residual covariance 4.19E+24				

Interpretation of Equations in the Bivariate VAR (2) System

From Table 6, the results show that all the lags of CP and LP series in (t-1) and (t-2) periods have significant effects on the CP series in current time period. This is obvious from their p-values which are less than the 5% level of significance. Also, the accuracy of the model is confirmed from the value of R^2 (= 0.936705); which is lower than the Durbin-Watson value of 1.869082. Also, the value of R^2 (= 0.936705) shows that about 94% of variation in the dependent variable (CP at current period t) is explained by both the CP and LP series in immediate past periods t-1 (2015) and two periods earlier t-1 (2014 and 2015) respectively. Also, the results show that only LP in (t-1) period has significant effect on the LP series in current time period. This is obvious from its p-value (< 0.0001) which is less than the 5% level of significance. In the same vein, the accuracy of the model is confirmed from the value of R^2 (= 0.881878); which is lower than the Durbin-Watson value of 1.937452. Also, the value of R^2 (= 0.881878) shows that about 88% variation in the dependent variable (LP at current period t) is explained only by LP series in immediate past period (t-1).

Table 6: VAR Granger Causality/Block Exogeneity

Dependent variable: CP			
Excluded	Chi-sq	Df	P-value
LP	6.576636	2	0.0373
All	6.576636	2	0.0373
Dependent variable: LP			
Excluded	Chi-sq	Df	P-value
CP	3.215635	2	0.2003
All	3.215635	2	0.2003

From Table 6, the Granger causality tests for CP and LP revealed a unidirectional relation that runs from the LP to the CP series. That is, the LP Granger causes the CP. This is evident from the p-value (= 0.0373) which is less than the significance level ($\boldsymbol{\alpha}$ = 0.05).

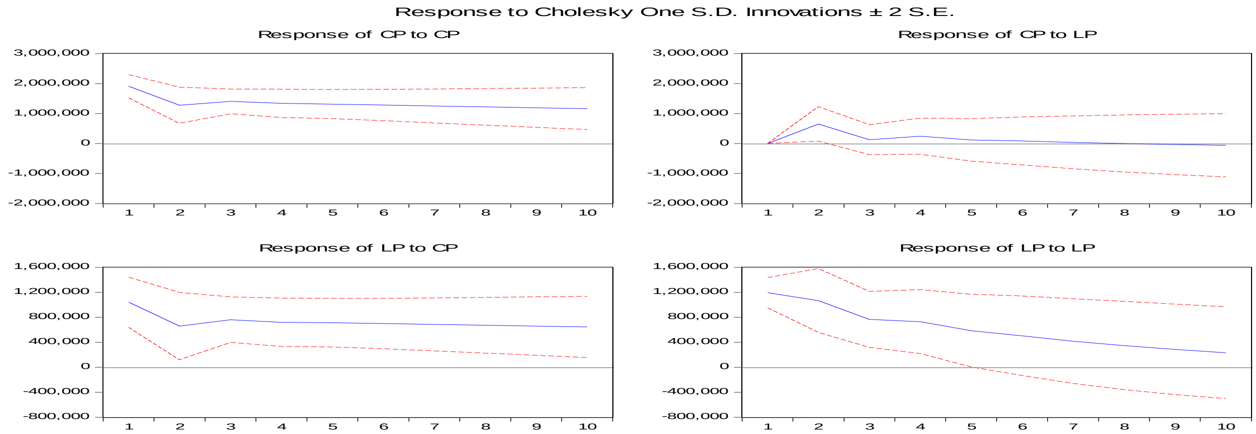

Figure 2: Impulse Response Graphs

From Figure 2, it can be deduced that cereals production (CP) is sensitive to land used for cereals production (LP) evident from the graph labeled "response of CP to LP" at the top right-hand side of Figure 2. However, land used for cereals production (LP) is not sensitive to cereals production (CP) as depicted by the graph labeled "response of LP to CP" at the bottom left hand side of Figure 2. This further buttressed the findings on Granger causality earlier discussed.

Discussion of Findings

This study investigated the effects of land under cereal production (LP) on cereal production (CP) in Nigeria using time series data from 1966 to 2016. The Vector Autoregressive (VAR) model was employed to analyze the time series variables. The six basic steps of VAR (p) model were carefully considered and were fulfilled accordingly in this study. In order to confirm the order of integration of the series, each of the series was subjected to unit root analysis using the Augmented Dickey-Fuller (ADF) approach. Results from the time plots presented as Figure 1 and results of the ADF tests stated in Table 1 showed that the two series are differenced stationary series of order one (i.e. I(1)). This means that the first condition of VAR (p) model was satisfied. Then, the results of the cointegration tests reported in Table 2 further revealed that these two I (1) series failed to satisfy the cointegration conditions which suggested that VAR (p) model was the appropriate model and not VECM. Hence, VAR analysis was carried out from lag 1 to lag 4 for the CP and LP time series variables. Results of the VAR optimal lag order in Table 3 showed that the least value of the selection criteria FPE and AIC occurred at lag 2 indicating that VAR (2) was the appropriate model for analyzing the CP and LP series. Based on the results presented in Table 5, all lags of CP and LP series in (t-1) and (t-2) periods have significant effect on the CP series in current time period for equation (2) while for equation (3), only LP in (t-1) period has significant effect on the LP series in current time period. Results of the Granger causality test in Table 6 showed that a unidirectional relationship runs from Land under Cereal Production (LP) to Cereal Production (CP). Finally, the effects of stochastic innovations to CP on LP and to LP on CP were explored using the impulse response function graph. It is evident from this graph that CP is sensitive to LP but the converse is not true based on the data used for this study.

Conclusions

Based on the sequence of statistical analyses carried out on the data on cereals production (CP) and land under cereals production (LP) in Nigeria from 1966 to 2016, it can be concluded that a unidirectional relationship exists between the two variables running from LP to CP. This implies that production of cereal crops in Nigeria can be predicted by the size of farmland used for planting cereal crops.

Recommendations

It is recommended that Federal Government of Nigeria needs to re-visit policies on land tenure system and embrace policies that will enhance easy acquisition of land by farmers for more cereals production.

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