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LONG RUN RELATIONSHIP BETWEEN SORGHUM YIELD, RAINFALL AND PRODUCER PRICE IN NIGERIA

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Abstract

Agricultural crop production in Nigeria is mostly rain fed. Therefore any change in climatic factors such as changes in rainfall could alter crop yield. On the other hand prices of agricultural commodities give signals to producers over the type and quantity of commodity to produce. This study investigated the relationship between sorghum yield, rainfall, and producer price in Nigeria for a period of 40 years (1970-2010). The stationarity properties of the data were tested using the Augmented Dickey-Fuller (ADF) test. The ADF test conducted on the specified time series data showed that all series were integrated of order I(1). The Johansen co integration test and vector error correction model (VECM) were applied to test for the long-run relationship among the variables and stability of the long-run equilibrium. The result indicated that there was at least one co integrating equation between the variables implying the existence of a long-run relationship between the variables examined. Consequently, policy and measures that can help farmers adapt to changing climatic factors as well as guarantee relative price for crops in general and sorghum in particular should be put in place to encourage the cultivation of sorghum and enhance its yield.

Keywords: *Sorghum, Rainfall, Producer price, Co integration, VECM, Nigeria*

1. Introduction

Agriculture as an important sector of the economy is the main source of food for over 170 million people in Nigeria. It employs about 60-70 per cent of the population and contributes between 30-40 per cent of the nation's Gross Domestic Product (Akintunde *et al.*, 2013). Agriculture is also the source of raw materials for the processing industries and a source of foreign exchange earnings for the country (Mohammed-Lawal & Atte, 2006).

Nigeria faces serious agricultural development challenges such as poor crop yield. Yield as a measure of agricultural productivity refers to the output that can be produced with a given level of inputs in a given area and it is an essential variable in shaping agricultural policy. Consequently, high variability in yield increases risk and makes the decision making process more important for producers (Bor & Bayaner, 2009). Every one per cent increase in agricultural yield translates to about 0.6 to 1.2 per cent decrease in percentage of the absolute poor (Thirtle *et al*., 2002), thus making agriculture an important component in poverty reduction and economic development of a nation (World Bank, 2005). The sector remains the main basis of livelihood for most rural communities in developing countries in general.

Sorghum is one of the staple food crops in the semi-arid tropics of Africa and Asia in general and Nigeria in particular. It is the main source of energy, protein, vitamins and minerals for millions of the poorest in these regions (FAO, 1995). It forms a very vital part of the diet which could be in the form of boiled porridge or gruel, unleavened bread, and rice-like products (Berenji & Dahlberg, 2004). Nigeria and Sudan produces about 63 per cent of Africa's total production (FAO, 1995). According to Aba, *et al*. (2004), 50 per cent of the total area devoted to cereal crops in Nigeria is covered by sorghum, with estimated area of 6.86 million hectares extended north-wards from Latitude 8°N to 14°N. It is a crop genetically suited to hot and dry agro ecologies where it is difficult to grow other food grains (ICRISAT, 2004). Most sorghum grains cultivated in Nigeria comes from the Northern Guinea and Sudan/Sahel ecologies in the following states: Adamawa, Bauchi, Borno, Gombe, Jigawa, Kaduna, Kano Plateau (Aba *et al.*, 2005). According to Samson *et al.* (1981), sorghum has greater untapped potentials than any other crop because of all the cereal crops, sorghum contributes about 50 per cent of the calories in Nigeria generally and about 73 per cent in the savannah regions of the country in particular. Sorghum displays a unique agricultural adaptableness to a world in ever growing need for more food (Koleoso & Olatunji, 1992). Sorghum has assumed greater importance in the economies of several African countries whose farmers are mostly subsistence producers with very limited income. Consequently, the potential of sorghum to be the driver of economic development in Africa in general and Nigeria in particular cannot be over emphasized given the significant benefits to Nigerian farmers and National food security.

Rain-fed agriculture dominates agricultural production in sub-Saharan Africa and covers about 97 per cent of total cropland and exposes agricultural production to high seasonal rainfall variability (Alvaro *et. al.*, 2009). Agricultural crop production in Nigeria is essentially rain fed and any change in climatic factors such as changes in rainfall will result in change in crop production. Unpleasant climate effects can influence farming outputs at any stage from cultivation through the final harvest (Akintunde *et al.*, 2013).

Given that so many smallholder farmers who account for the majority of the food crops produced in Nigeria rely directly on rainfall for their foods and livelihoods, changes in rainfall present a major threat. In reality the IPCC's fourth assessment report suggest that some African countries may see yields from rain fed agriculture fall by as much as 50 per cent by 2020, if production practices remain unchanged (IPCC, 2007). Rainfall characteristics determine crop yield (Audu, 2012). Where rainfall is optimum, crop yield is high; if low, low crop yield and if too high, poor yield partly due to flooding (Ojonigu *et al.*, 2009). Rainfall within the tropics is highly variable and it is the most important variable affecting crop yield (Ifabiyi & Omoyosoyo, 2011). Rainfall is by far the most significant element of climate change in Nigeria (Adejumo, 2004). Several studies have shown that climatic parameters such as rainfall, sunshine, temperature and evaporation) are closely interconnected in their influence on crops (Oguntoyinbo, 1986; Ayoade, 2002; Ayoade, 2004 and Cicek & Turkogu, 2005). However, according to Hodder (1980) of all the climatic parameters affecting crop production and yield, moisture is the most important. Moisture is largely obtained from rainfall which in the tropics is cyclical and fairly dependable (Ezedinma, 1986). Even if there is adequate rain, its irregularity can affect yields negatively if rains fail to arrive during the crucial growing stage of the crops (Rudolf & Hermann, 2009).

In a competitive economic system, prices of commodities give signals to the producers concerning the type and quantity of commodity to be produced in a particular place at a particular time (Reddy *et al*., 2009). Thus, price relationships have a significant influence on decisions regarding the type and quantity of agricultural production activity. Farmers are generally believed to be responsive to producer prices (Ezekiel *et al.*, 2007). Producers are more anxious about low prices, which may threaten their living standards as well as their longer term capability when income is too low to provide for the farm family or for the needs of the farm. The prices of most farm commodities do not stay constant throughout the season; they follow some regular seasonal patterns. Seasonal prices are at their lowest at harvest and their pinnacle a few weeks to the new harvest usually for storable products such as cereals and leguminous grains (Olukosi *et al*., 2007). It is generally believed that farmers have enough power to determine the physical process of agricultural production, implying that the decisions on what to produce, how to produce and which inputs to use are in the hands of the farmers and the farmers take the prices as decision-making factor (Bor & Bayaner, 2009). Thus, rational producers are expected to increase the use of inputs in response to crop price increases, suggesting that producers base their decisions on the expected crop prices (Bor & Bayaner, 2009).

Given the significance of sorghum to the country as a staple crop and its potential to improve the well being of smallholder resource poor farmers, the susceptibility of sorghum to climate and non climatic variables is of particular concern to policy makers for the purpose of planning. This is because the dependence of agricultural production especially crops on weather conditions such as rainfall can affect actual yield which may be greater or less than what was planned (Olukosi *et al*., 2007), price relationships have a considerable influence on decisions concerning the type and quantity of agricultural production activity and farmers are by and large believed to be responsive to producer prices (Ezekiel *et al.*, 2007). It is in line with this, that this study examined the relationship between sorghum yield, rainfall and producer price in Nigeria. It is hypothesized that rainfall and producer prices have significant relationships with sorghum yield in Nigeria. This paper contributes to the existing literature investigating the impacts of climate change and price on crop yields.

2. Data and Methodology

2.1 Data sources

Data used for this study were obtained from the Central Bank of Nigeria (CBN, 2012), Food and Agriculture Organization Statistics (FAOSTAT, 2014) Publication and Nigeria Meteorological Agency. The study covered a period of 40 years (1970-2010). Annual data on sorghum yield (tonne/ha), rainfall (mm) and producer price of sorghum in local currency (Naira/ tonne) represented by *SGY*, *RF* and *PPSG* respectively were collected from the mention sources.

2.2 Methodology

This study aimed at determining the relationship among sorghum yields, rainfall and producer price of sorghum in Nigeria. The use of time series data for analysis demands the investigation of presence of unit root in the data. This is to ensure that the variables used in the regressions are not subject to spurious regression. For this reason, Unit Root Test was carried on the variables. The Johansen co-integration test and vector error correction model (VECM) were employed to examine the long-run relationship and the stability of the equilibrium among sorghum yields, rainfall and producer price in Nigeria. The estimation procedure takes the following forms:

2.2.1. Unit Root Test

Given that the initial step in carrying out a time series analysis is to test for stationarity of the variables (in this case, sorghum yield, rainfall and producer price series), Augmented Dickey-fuller (ADF) test was used to check for unit root for the variables used for this study. A series is said to be stationary if the means and variances stay constant over time. It is denoted as I(0), meaning integrated of order zero. Non stationary stochastic series have changing mean or time varying variance. All the variables used in this study were first tested for stationarity. The rationale was to overcome the problems of spurious regression. A stationary series tends to always return to its mean value and variations around this mean value. A variable that is non-stationary is said to be integrated of order *d*, written as *I(d),* if it must be differenced *d* times to be made stationary. In the same way, a variable that has to be differenced once to become stationary is believed to be *I(1)* that is integrated of order I(1). According to Gujarati (2003), the Augmented Dickey Fuller (ADF) test entails running a regression of the form:

$$\Delta Z_t = \beta_1 + \beta_2 t + \delta Z_{t-1} + \sum_{t-1}^{m} \alpha_1 \Delta Z_{t-1} + \varepsilon_t \quad (1)$$

Where Δ= the change operator; Z_t = variable series (soybean yield (*lnSGY*), rainfall (*lnRF*) and producer price (*lnPPSG*) being investigated for stationarity); Z_{t-1} = Past values of variables; $\Delta Z_{t-1} = (Z_{t-1} - Z_{t-2}), \Delta Z_{t-2} = (Z_{t-2} - Z_{t-3})$, e.t.c; t = time variable and ε_t is the white noise error. The null hypothesis that δ = 0 means existence of a unit root in Z_t or that the time series is non-stationary. The decision rule is that if the computed ADF statistics is greater than the critical at the specified level of significance, then the hull hypothesis of unit root is accepted otherwise it is rejected. In other words, if the value of the ADF statistics is less than the critical values, it is concluded that Z_t is stationary i.e Z_t ~ I(0). When a series is found to be non-stationary, it is first-differenced (i.e the series $\Delta Z_t = Z_t - Z_{t-1}$ is obtained and the ADF test is repeated on the first-differenced series. If the null hypothesis of the ADF test can be rejected for the first-differenced series, it is concluded that Z_t ~ I(1).

2.2.2. Co integration test

The rationale for carrying out co integration is to identify or find out whether there is long-run equilibrium relationship between variables. When two or more data series have a long-run equilibrium relationship, it means that they move together closely, they will not separate from each other in the long run and are co integrated. An impulse will only make them to be apart from each other in the short run. However, in the long run, they will automatically resume equilibrium. The most commonly used methods for co integration test are the Engle-Granger two step test (Engle and Granger, 1987) and the Johansen Maximum Likelihood procedure (Johansen & Juselius, 1990). This study adopts Johansen Maximum Likelihood procedure because it allows for all feasible co integration relationship and the number of co integrating vectors to be verified practically. The starting point for Johansen co integration test is the vector auto regression (VAR) of order *p* given by: $Z_t + \phi + A_1 Z_{t-1} + \ldots + A_p Z_{t-p} + \varepsilon_t$. This VAR can be re-written as:

$$\Delta Z_t = \phi + \sum_{i=1}^{n} \Gamma_i \Delta Z_{t-1} + \Pi Z_{t-1} + \varepsilon_t \quad (2)$$

Where, $\Pi = \sum_{i=1}^{p} A_i - I, \Gamma_i = -\sum_{j=i+1}^{p} A_j$ and Z_t (*lnSGY, lnRF* and *lnPPSG*) is a (n x 1) vector of all the non-stationary *l(1)* variables in the study, ϕ is a (n x 1) vector of parameters (intercepts), ε_t is an kx1 vector of innovations or random shocks. Γ_i and Π are (n x n) matrices of parameters, were Γ_i is a (n x 1) vector of coefficients of lagged Z_t variables. The Π is a *(n x 1)* is a long-run impact matrix which is product of two *(n x 1)* matrices. If the coefficient matrix Π has reduced rank *r<n*, subsequently there exist *(n x r)* matrices *α* and *β* each one with rank *r* such that Π = *αβ′* and *β′Zt* is stationary. The *r* is the

number of co integrating relationships, the elements of α is known as the adjustment parameters in the vector error correction model and each column of β is a cointegrating vector. It can be revealed that for a known r, the maximum likelihood estimator of β defines the combination of $Zt-1$ that yields the r largest canonical correlations of ΔZt with $Zt-1$ after correcting for lagged differences and deterministic variables once present. Johansen (1995) suggested two different likelihood ratio tests, the trace test which tests the null hypothesis of r co integrating vectors against the alternative hypothesis of k co integrating vectors and maximum eigenvalue test, which tests the null hypothesis of r co integrating vectors against the alternative hypothesis of $r + 1$ co integrating vectors.

2.2.3 Vector Error Correction model (VECM)

An error correction model was employed to model the causal influence among the non stationary variables with evidence of long-run relationship. The vector error correction model is useful for the evaluation of a short term adjustment which adjusts towards the long run equilibrium in each time period. If the variables are found to be co integrated, a vector error correction model (VECM) is estimated because a co integrating relationship deals only with long-run relationship without considering the short-run dynamics. Thus, if the series *lnSGY,* ln*RF* and *lnPPSG* are found to be *I(1)* and co integrated, then the ECM model is represented by the following equations:

$$\Delta \ln SGY_t = \varphi_1 + \sum_{i=1}^{n} \beta_{1i} \Delta \ln SGY_{t-1} + \sum_{i=1}^{n} \sigma_{1i} \Delta \ln RF_{t=1} + \sum_{i=1}^{n} \sigma_{1i} \Delta \ln PPSG_{t-1} + \alpha ECT_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta \ln RF_t = \varphi_2 + \sum_{i=1}^{n} \beta_{2i} \Delta \ln SGY_{t=1} + \sum_{i=1}^{n} \sigma_{2i} \Delta \ln RF_{t-1} + \sum_{i=1}^{n} \sigma_{2i} \Delta \ln PPSG_{t-1} + \alpha ECT_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta \ln PPSG_t = \varphi_3 + \sum_{i=1}^{n} \beta_{3i} \Delta \ln SGY_{t=1} + \sum_{i=1}^{n} \sigma_{3i} \Delta \ln RF_{t-1} + \sum_{i=1}^{n} \sigma_{3i} \Delta \ln PPSG_{t-1} + \alpha ECT_{t-1} + \varepsilon_t \quad (5)$$

Where *lnSGY* is logarithm of sorghum yield in year t (tonne/ha), *lnRF* is logarithm of annual rainfall (mm), *lnPPSG* is the logarithm of producer price for sorghum (naira/tonne), *ECT* is the error correction term, Δ is the difference operator and ε_t is the error term which takes care of other variables that could have influence on sorghum yield but not specified in the model and while n is the optimal lag length orders of the variables.

3. Results and Discussion

3. 1 Augmented Dickey Fuller Unit Root Test

Augmented Dickey-Fuller (ADF) stationarity test was carried out on the logarithmic form of the variables (*lnSGY,lnRF and , lnPPSG*). Table 1 shows the result of the ADF test for levels as well as for first difference of the variables. The results show that test at level failed to reject the null hypothesis of non-stationary of all the variables examined. This means that all the variables are non-stationary at levels. However, after first difference, the null hypothesis is accepted. This shows that all the variables used are integrated of order one [i.e *l*(*1*)].

Table 1. Augmented Dickey Fuller (ADF) Unit Root Test

Variables	Test	ADF Stat	Critical Values		
			1%	5%	10%
ln SGY	Level	-3.0362 (0.0405)	-3.6156	-2.9411	-2.6091
	1st difference	-4.6210*** (0.0005)	-3.6210	-2.9434	-2.6102
ln RF	Level	-1.4224 (0.5618)	-3.6056	-2.9369	-2.6069
	1st difference	-7.7244*** (0.0000)	-3.6104	-2.9389	-2.6079
ln PPSG	Level	-0.8507 (0.7931)	-3.6105	-2.9389	-2.6079
	1st difference	-8.6171*** (0.0000)	-3.6105	-2.9389	-2.6079

Source: Author's computations using E-views software
Note: Figures in parentheses are p- values; *** indicates variable is integrated of order I(1) at 1% level of significance; Lag selection is automatic based on Schwartz Bayesian Criterion (SBC)

3.2 Co integration Test Result

Since, most of the variables follow order one [I (1)] the next step was to test if there exists a long run relationship (co integration) among the variables. The Johansen's co integration tests was estimated with linear deterministic trend in a Vector Auto Regression (VAR) model of order two and with a lag length of 2 which was found to be the most ideal for the data series. The Johansen co integration rank test results are presented in Table 2. Both the trace statistics and eigenvalue statistics in the Table 2 show that there is a unique long run relationship among the variables because in both cases the test shows at most one co integrating equation at 5 percent level of significance. Thus, the Johansen co integration test confirms the existence of a unique long run relationship among the variables. Consequently, co integration test results as shown in Table 2, indicates that the dependent variable Sorghum yield is co integrated with rainfall and producer price, as such the test statistics strongly reject the null hypothesis of zero co integrating vectors in favour of the alternative hypothesis that there is at least one co integrating vectors. Therefore, the results in Table 2 confirm that the two variables are important determinants of sorghum yield in Nigeria.

Table 2. Co integration Test Results

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.4864	40.0562	35.1928	0.0138	25.3224	22.2996	0.0183
At most 1	0.2554	14.7338	20.2618	0.2420	11.2043	15.8921	0.2371
At most 2	0.0887	3.5294	9.16455	0.4867	3.5295	9.1645	0.4867

Source: Author's computations using E-views software
Note: Trace test and Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values

3.3 Vector Error Correction Estimates

Given the existence of a co integrating relationship between the dependent and independent variables as shown by the Johansen co integration test, a VECM was estimated. The long-run effects of rainfall on sorghum yield shows that rainfall was positively related to sorghum yield and statistically significant at 10 per cent level. This means that a one percent increase in rainfall will increase sorghum yield by 28 per cent. On the other hand, producer price of sorghum was found to have a significant impact on sorghum yield at 5 per cent with a negative coefficient of 0.16, suggesting that a 1 percent decrease in the producer price of sorghum will lead to a 16 per cent decrease in the yield of sorghum in the long-run as farmers will channel their resources to other crops with better prices.

The results revealed that the coefficient of the error correction term (ECT-1) which measures the adjustment towards long-run equilibrium was negative as expected and statistically significant at 5 per cent with a coefficient of -0.029 (Table 3), implying that the deviation in sorghum yield from the long-run equilibrium position is corrected by about 3 per cent in the current period. However, it will take a longer time, given that the value is very small. Thus, in the short run sorghum yields are adjusted by 3 per cent of the past years divergence from equilibrium, this validate the steadiness of the system. It also means that in the case of disequilibrium, the system will converge in the direction of the equilibrium path. This is the error corrected each year due to the disequilibrium between the short-run and long-run model.

Table 3. Vector Error Correction Estimates of Sorghum Yield in Nigeria

Long-run estimates			
ln SGY			1.0000
ln RF			0.2847 [2.2128]*
ln PPSG			-0.1601 [-2.0967]*
Constant			-18.6249 [-6.7261]***
Short-run estimates			
Error Correction:	Δ (ln SGY)	Δ (ln RF)	Δ (ln PPSG)
ECT-1	-0.0291 [-2.1722]*	-0.0681[-1.2317]	-0.3392 [-4.8455]***
Δ (ln SGY (-1))	-0.3263 [-1.8026]*	0.0931 [0.4035]	-0.1735 [-0.5941]
Δ (ln SGY (-2))	-0.0040 [-0.0217]	-0.2044 [-0.8704]	0.0903 [0.3039]
Δ (ln RF (-1))	-0.0223 [-0.1648]	-0.1421 [-0.8224]	-0.1723 [-0.7879]
Δ (ln RF (-2))	0.0815 [0.6116]	0.0148 [0.0871]	-0.0363 [-0.1690]
Δ (ln PSG (-1))	-0.0331 [-0.3082]	-0.1921 [-1.4027]	-0.6085[-3.5124]***
Δ (ln PSG (-2))	-0.0041 [-0.0344]	0.0205 [0.1355]	-0.5281 [-2.7554]**
Diagnostic Statistics			
R-squared	0.1279	0.1753	0.3590
Adj. R-squared	-0.0409	0.0157	0.2349
Sum sq. resids	1.3011	2.1144	3.3845
S.E. equation	0.2049	0.2612	0.3304
F-statistic	0.7579	1.0984	2.8942
Log likelihood	10.1931	0.9674	-7.9702
Akaike AIC	-0.1681	0.3175	0.7879
Schwarz SC	0.1336	0.6192	1.0896
Mean dependent	0.0228	0.0173	0.1632
S.D. dependent	0.2008	0.2632	0.3777

Source: Author's computations using E-views software

Note: -statistics in [ ]; the asterisk *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively

4. Conclusion

The study used annual time series data for the period 1970-2010 to examine the long-run relationship between sorghum yield, rainfall and producer price of sorghum in Nigeria. Augmented Dickey-Fuller (ADF) test was employed check the stationarity of the variables.. The results found that all variables were non-stationary at level but they become stationary after the first difference implying that all variables were integrated of order one i.e. I(1). Since the variables were integrated of the same order, Johansen co integration technique was applied to examine long run relationships between the variables. The results suggested one co integrating equation an indication that the variables were co integrated. Error Correction model (ECM) was used to confirm the stability of this relationship and the model seem to be convergent towards the long-run equilibrium. Given the importance of sorghum to the nation as a staple crop and its potential to enhance the well being of smallholder resource poor farmers who are the major players in agricultural production in Nigeria, the need to boost the yield of sorghum cannot be overemphasized. Consequently, policy aimed at enhancing the yield of this crop could be achieved by putting in place policy and measures that can help farmers adapt to changing climatic factors. In addition, guarantee relative price for sorghum crop should be introduced to improve prices received by farmers. This is important because higher prices for farm produce would lead to increased value of farm output which in turn leads to higher consumption and standard of living. This could have strong implications for both food security and food independence.

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