Effects of Climate Variability on Grain Yield in Nigeria: An FM-OLS Model Approach

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Abstract

The study empirically explored the effects of variability in climate parameters on yield of two grain crops grown in Nigeria (millet and sorghum). This study was based on time series data obtained from various sources spanning from 1970 to 2012. Data obtained were analyzed using fully Modified Ordinary Least Square (FM-OLS) approach. The results showed that land area expansion (lnarea) exerted a significant effect on yield of sorghum in the study at a 5% level of significance within the period of study. For millet, the results indicated that climate variable (mean annual temperature), CO_2 emissions as well as land area expansion significantly impacted on the yield of the crop in the study. It is recommended that land expansion should be accompanied by intensive utilization of inputs which could help to boost the yield of sorghum and millet in the study area.

Key Words: Climate change, climate Variability, grain yield, FMOLS, Cointegration

1. Introduction

There is sufficient evidence that the world has been witnessing long term changes in climate patterns and variability with rapid acceleration in recent decades (Ahmed, Diffenbaugh and Hertel, 2009). Considerable shifts in long term temperature and rainfall averages, sea levels, frequency and intensity of droughts and floods, and their variances have been observed (Inter-governmental Panel on Climate Change, IPCC, 2007). Since temperature and precipitation are direct inputs in agricultural production, climate change can therefore be expected to impact on agriculture, potentially threatened established aspects of farming system (Hassan, 2010, Christensen and Hewitson, 2007).

The synthesis Report of the fourth assessment of IPCC stated, with high confidence, thatagricultural production and food security in many African countries and regions were likely to be severely affected by climate variability and change (IPCC, 2007). Food and Agricultural Organization (FAO, 2000) also noted that extremes of heat and cold, droughts and floods, and various forms of violent weather phenomena have wreaked havoc on the agricultural systems in African region.

Nigerian agriculture which is largely based on weather sensitive agricultural production system is particularly vulnerable to climate variability and change, as food production has been threatened by vagaries of weather (Dinar, Hassan, Kurukulasunya, Benhin and Mendelsohn, 2006). According to the report by International Food Policy Institute (IFPRI, 2012), although maize, millet, rice and sorghum are the major cereal crops in Nigeria and the West Africa region, the yields from these crops were very low compared to the world average and even other regions of Africa. Climate variability and change posed additional serious challenge in increasing agricultural productivity in Sub-Saharan Africa (IFPRI, 2012, World Bank, 2009, USAID, 2009, Von Braun, 2007). The report by IPCC AR5 posits that globally rising temperatures would make it harder for crops to thrive, perhaps reducing production over all by as much as 2 percent each decade for the rest of the century. During the period, demand is expected to rise as much as 14 percent each decade the report found, as the world population is projected to 9.6 billion in 2050, from 7.2 billion (IPCC, 2013).

Food grain production is essential in developing countries, especially Sub Saharan Africa (SSA) where agriculture is the main source of food and livelihood (Badiane and Delgado, 1995). The vulnerability of agriculture to weather in this region is evident as about 97% of agricultural land is rainfed (Rockstrom *et al*., 2004). The impact of climate variability and change on crop yield is a major concern in SSA.

Recently, international tensions and concerns are heightening over what the impact of climate variability will have on environment and agricultural production (Apata *et al.,* 2009, Building Nigeria's Response to Climate Change, BNRCC, 2008). Nigeria Environmental Study Team (NEST, 2004), Same goes, how agricultural production and food distribution system will be further stressed up by the shifting of temperatures and precipitating belts, especially if changes are rapid and not planned for (Integrated Regional Information Networks [IRIN], 2013;NEST, 2004).

Concern about potential adverse impact of climate variability and change have triggered what could be named as Impact Assessment Research since the early 1990's (Adam, Fleming, Chang, McCarl and Rosenzweig, 1995; Fischer, Frohberg, Parry and Rosenzweig, 1994; Reilly , 1994, Rosenesweig and Parry, 1994, Kane, Reilly, and Tobey, 1991). Although, some past studies have examined the effect of climate change on agriculture, at the national, regional and global scale, there is need to identify the impact of climate change on different sectors of the economy for planning and policy making.

Conceptual Framework

The study is partly anchored on the theory of production theory which is also anchored on the neo-classical economists' tradition. Neo-classical producer theory provides a prediction of how producers (farmers) make production decisions in response to exogenous factors, such as input and output prices, environmental and technological constraints. Duality theory produces a methodology for predicting those decisions from observatory on producers' cost and profits. Using neoclassical theory, the long run effects of a climate change can be estimated in one of the two ways.

First, a supply or yield function can be estimated directly with a data set containing observations on yields, input and output prices, soil characteristics and climate variables. Alternatively, the economic impacts can be predicted from as estimated profit or cost function.

The two main techniques mostly used in evaluating the effect of climate change on yields include: (1) crop growth models and (2) regression analyses. Crop growth models are widely used and produce precise crop yield responses to weather events. In their study, Rosenzweig and Parry (1994) provided a global assessment of climate change on world food supply and predicted grain yield losses of up to 10% in several SSA countries between 1990 and 2080. However crop growth models require daily weather data and are calibrated under experimental conditions. Alternatively, regression analyses allow the quantification of weather changes on crop yields in an actual cropping context.

Ayinde, Muchie and Olatiyi (2011) estimated the impact of weather changes on agricultural productivity in Nigeria. Among the few regression based impact assessments of future climate change on grain yield in Nigeria, Aye and Ater (2012) focused on maize and rice and Ayinde, Ojehomon, Daramola and Falaki (2013) studied the effect of climate change on rice production in Niger State Nigeria. They all applied econometric approaches to model the impact of climate change and variability on the grain yields. Similarly, this study applied the econometric approach to grain production and supply in Nigeria.

The broad objective of this study was to explain how variability in climate parameters has impacted on grain yield in Nigeria over time, particularly, millet and sorghum. These are among the most important cereal grains grown in Nigeria.

2. Research Methods

The study was carried out in Nigeria. The Federal Republic of Nigeria is in West Africa, located between latitudes 40 to 140 North and between longitudes 202' and 14030' East. To the North, the country is bounded by Niger Republic (1497km) and Chad (853km) to the West by Benin Republic (773km) to East by the Cameroon Republic (1690km) and to the South by Atlantic Ocean. Nigeria has a land area of about 923,769km2 (FOS, 1989; World Fact book ,2014), a north south length of about 1450km and west east breath of about 800km. Its total land boundary is 4047km while the coastline is 853km.

Data Source and Collection Procedure

This study was based on time series data obtained from various sources spanning from 1970 to 2012. The aggregate national data on production of selected grains like millet and sorghum were collected from Food and Agricultural Organization statistical website (FAOSTAT), other sources of the data collection include various editions of the Bureau of statistics (NBS), Central Bank of Nigeria statistical bulletin, United Nations and World Bank climate data bases. The study made use of agronomic, input and climate data. The input and agronomic data were collected from FAOSTAT and NBS while climate data was obtained from UNDP and World Bank Climate data base. Aggregate annual data on production, yield, Area harvested, and fertilizer quantity applied were collected.

Empirical Model

In other to find out if the relationship between economic variables is spurious or nonsensical. Philip Perron (pp) test was used to examine each of the variables for the presence of a unit root. The pp test is a non-parametric test, but it was found to produce a superior result that corrects for serial correlation and heteroscedasticity. The pp test is also known to be better in the presence of regime shift which is a problem usually encountered with Africa macroeconomic data (Yusuf and Yusuf, 2007). On application of pp test variables attained stationarity after differencing once and thus, one may conclude that the variables are integrated of the order one, 1(1). Stationarity is confirmed when the test statistic is greater that the critical value in absolute terms

The main objective of the study was analyzed using Fully Modified Ordinary Least Square (FM-OLS) Regression. The FM-OLS estimation method is an approach to regressions for time series taking advantage of data non stationarity and cointegrating links between variables approach. It produces reliable estimates for small sample size and provides a check for robustness of the results. The FM-OLS method was originally introduced and developed by Philips and Hansen (1990) for estimating a single co-integrating relationship that has a combination of I(1). This method could be preferred to the Engle Granger techniques in introducing appropriate correction to overcome the inference problem in Engle Granger method and hence, the t-test for long-run estimates is valid (Himansu and Lester, 2007). The Fully Modified Ordinary Least Squares (FM-OLS) method utilizes "Kernal estimators of the Nuisance parameters that affect the asymptotic distribution of the OLS estimator. In order to achieve asymptotic efficiency, this technique modifies least squares to account for serial correlation effects

Table 1: Unit Root Test Result

and test for the endogeneity in the regressors that result from the existence of Co-integrating Relationships" (Rukhsana and Shahbaz, 2008).

The model is specified as follows, following Philips and Hansen (1990):

y_{it} = f(Ait, Tt, P, CO2, fert) ………………………...1

Where

yit= yield for crop i at time (tonne/hectare)

Ait= Area harvested for crop i at time t (hectare); T = mean annual temperature (Oc degree centigrade); P= total annual rainfall (mm); CO2 = total annual CO2 emission (kt)

Fert = fertilizer applied (tonne).This is explicitly expressed as:

Intermediate Phillips-Perron test results for unit root

Series	***Prob.***		***Bandwidth***		***Obs***	
	Level	**1st Difference**	**Level**	**1st Difference**	**Level**	**1st Difference**
CO2	0.3613	0.0000	2.0	0.0	42	41
FERT	0.1870	0.0000	1.0	7.0	42	41
LNCO2	0.1083	0.0000	2.0	4.0	42	41
LNFERT	0.1156	0.0000	7.0	7.0	42	41
LNMLTA	0.3742	0.0000	3.0	3.0	42	41
LNMLTP	0.9859	0.0054	0.0	0.0	42	41
LNMLTYD	0.0363	0.0000	1.0	4.0	42	41
LNRAIN	0.0001	0.0000	9.0	25.0	42	41
LNSGM	0.1125	0.0000	2.0	0.0	42	41
LNSGMA	0.0279	0.0000	3.0	1.0	42	41
LNSGMP	0.6263	0.0000	3.0	1.0	42	41
LNSGMYD	0.0448	0.0000	3.0	14.0	42	41
LNTEMP	0.9991	0.0000	2.0	3.0	42	41
MLTA	0.3864	0.0000	3.0	3.0	42	41
MLTP	0.1674	0.1032	1.0	4.0	42	41
MLTYD	0.0924	0.0000	2.0	6.0	42	41
RAIN	0.0001	0.0000	11.0	23.0	42	41
SGM	0.1585	0.0000	2.0	0.0	42	41
SGMA	0.0649	0.0000	3.0	3.0	42	41
SGMP	0.9480	0.0000	3.0	13.0	42	41
SGMYD	0.1166	0.0000	5.0	16.0	42	41
TEMP	0.9995	0.0000	2.0	3.0	42	41
YEAR			Dropped from Test			

Source: Computed from CBN Data by Authors, 2015

$\log y = \beta_0 + \beta_1 A_{it} + \beta_2 T + \beta_3 P + \beta_4 CO_2 + \beta_5 Fert + e$……………………………………......................2

β_0- β_5 = parameters to be estimated; e = stochastic error term.

3. Results and Discussion

Prior to the estimation of the impact of climate variability on grain yield, the variables to be used were subjected to stationarity tests (CO2, FERT, Rain, Temp, Area harvested, yield) Philips-perron (PP) unit root test was used in determining the stationarity of the variables under consideration and the results were presented in Table 1.

Impact of climate variables on grain yield based on estimates from Fully Modified Ordinary Least Squares (FM-OLS)

The FMOLS parameter estimates of the cointegration regression model applied in analyzing the climate variables alongside CO2 emission and fertilizer input application effects on grain yields in sorghum and millet in Nigeria over the period of study are summarized in Table 2. It was indicated from the result that land area expansion (lnarea) exerted a significant effects on the yield of sorghum in the study at a 5% level of significance within the period of study. All other variables, including the climate variables showed no significant effect on the yield of sorghum.

The slope coefficient of -7348.971 sorghum implied that land area expansion by a single percent resulted in yield decrease by 7,348.97 tonnes in the period of study. This could be supporting law of decreasing marginal productivity (Elodie 2011) or also imply that land expansion was probably not accompanied by intensive utilization of inputs such as high yielding seeds, appropriate fertilizer and pesticides which could have boosted the yield of sorghum.

However, in terms of the model's diagnosis, it was found that the model also had residuals which were normally distributed with a Jarque Bera statistic of 5 at p = 0.21 (i.e. p>0.10), thus affirming that the distribution of the residuals of the estimated model was normal. Similarly, the cointegration test using Engle-Granger Tau statistic recorded a value of -5.649808 (p<0.05) implying that we have to reject the null hypothesis which held that "series are not cointegrated" at 5 percent. The series are therefore deemed as cointegrated and could be reliably used for forecasting. The test for model fitness gave an R squared value of 0.58, which implies that 58% of the variations in yield of sorghum were accounted for by variability in the independent variables included in the regression model. The fact that the correlogram of the residuals squared did not show significant values at 5% implies that the threat of serial correlation at the various lags examined in the study was not severe in the model. All these affirmed that the model had desirable properties of OLS.

For millet, the results indicated that climate variable (mean annual temperature), CO2 emissions as well as land area expansion significantly impacted on the yield of the crop 1%,5% and 1% respectively.

From Table 1, the entire test variable for determining impact of climate variability and change on grain yield were not stationary at levels but became stationary in difference on the basis of the Philip Perron probability level. The null hypothesis of non-stationarity was rejected after the first difference.

Their slope coefficients in Table 2 were -10493.78 (p<0.01), 530.58 (p<0.05) and -7348.97 (p<0.01) respectively. These results implies that while temperature increase by one percent resulted in mean annual yield decrease in the study by 10, 493.78 tonnes, curiously increase in CO2 emissions by a percent resulted in an increase in yield by 530.58 . However, the direction of impact of land area expansion was similar to that of sorghum which indicated a negative impact of land expansion. It was specifically indicated that a unit or percentage increase in land area in the country resulted in a yield decrease by 7,348.97 tonnes within the period of study.

Table 2: Results of FMOLS parameter estimates to model the effect of climate variables, CO2emissions and fertilizer input utilization on yields of sorghum and millet in Nigeria (1970-2012)

Dependent variables:		**Sorghum Yield**			**Millet Yield**	
Independent variables	***Coeff.***	***Std. error***	***t-Statistic***	***Coeff.***	***Std. Error***	***t-Statistic***
Lnrain	-754.797 (-0.438)	1725.085	-0.438	1694.356 (0.879)	1927.207	0.879
Lntemp	-10493.780 (-0.948)	11067.670	-0.948	-44258.49 (-3.507)**	12619.08	-3.507***
lnco2	530.578 (0.429)	1235.522	0.429	3405.613 (2.347)*	1450.838	2.347**
Lnfert	-98.075 (-0.171)	574.806	-0.171	-681.471 (-1.000)	681.691	-1.000
Lnarea	-7348.971 (-3.655)**	2010.418	-3.655***	-6780.010 (-3.454)**	1963.066	-3.454***
C	157562.500 (2.438)*	64638.670	2.438**	223704.40 (3.199)**	69933.59	3.199***
@TREND	240.718 (3.400)**	70.790	3.400***	201.006 (3.362)**	59.783	3.362***
R-squared	0.58			0.52		
Adjusted R-squared	0.50			0.44		
Jarque Bera Statistic	5			3.76		
Engle-Granger tau-statistic	-5.649808**			-4.933853		
Mean VIF	3.42265			2.410132		
Remark on Correlogram of Residuals Squared	Significant at 5% only I the first 7 lags but not significant thereafter			Significant at 5% only I the 3 and 4th lags but not significant thereafter		
Mean dependent variable	11023.4			11349.18		

Source: Output of result from E view

Note: "***" = Figures significant at 1% level"**" = figures significant at 5% level "*" = figures significant at 10%

The model fitness test indicated an R^2 of 0.52 which implies that 52 percent of the variation in yield of millet were accounted for by increase or decrease in the independent variables included in the model. This is a fairly good result. From the Jarque-Bera statistic of 3.76 ($p< 0.16$) recorded as well as the squared correlogram at various lags which were not significant at 5 nor 10 percent, implied that the residuals were normally distributed and devoid of serial correlation at various lags. The Engel-Granger Tau statistics of -4.933853 ($p<0.05$) indicated that the series were cointegrated as the null hypothesis of no cointegration was rejected at 5 percent. The low mean VIF recorded too (2.41) means that the threat of sever multi collinearity is ruled out in this model. All these confirm that our model is fit and have all desirable econometric properties good enough for forecasting and economic analysis.

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4. Conclusion

The results obtained from the regression analyses on effect of climate variability on yield of grain reveals that temperature, CO2 and area harvested affected the yield of grains under study. It is recommended that land expansion should be accompanied by intensive utilization of inputs such as high yielding seeds, appropriate fertilizer and pesticides which could help to boost the yield of sorghum and millet in the study area. The government has a role to play in this regard by using the Ministries of Agriculture and Natural Resources to source and make the agricultural inputs readily available to farmers at the growing season when they are most needed and at rates that are affordable.

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