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Stochastic Cycles of Atmospheric Energy and Impact on Macro-economic Buoyancy in Nigeria (2004 - 2012)

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Abstract

Fragility of Aggregate Agricultural Output (AOP) and Gross Domestic Product (GDP) in response to stochastic atmospheric energy, could pose some risks of distortions in macro-economic buoyancy in Nigeria. The relationship between agricultural output and aggregate economic growth is an essential economic issue that has engaged the brilliant minds of development economists. There is need for research on the entry points of erratic atmospheric energy (Temperature and rainfall) into Nigerian economy. This study analyzed the relationship between stochastic cycles of climate variables and buoyancy of Aggregate Agricultural Output (AOP) and Gross Domestic Product (GDP) over different time scales. Time series data (2004-2012) on climate elements and macroeconomic variables were obtained from Meteorological Centre and Central Bank of Nigeria (CBN) respectively. Econometric tools (multiple regression analysis) was used to analyze the data. The results indicate that stochastic cycles of climate elements correlates significantly ($p<0.05$) with distortions in aggregate agricultural buoyancy, especially, at lower time scales (0.83) but weaker (0.17) with longer time scales. Sensitivity analysis shows that temperature variation created an impact factor of 71%, and was considered as the most important climate element that significantly influenced Aggregate Agricultural Output (AOP) and Gross Domestic Product (GDP). Short run swift adaptive macro-economic regulatory policies and practices for climate extremes were recommended to enhance a stable economy and food supply systems in Nigeria.

Key Words: Stochastic cycles, Atmospheric energy, macro-economic, buoyancy.

Introduction

The atmosphere is affected by the environment and the environment is inturn affected by the atmosphere. Atmospheric energy, includes all influences derived from climate in the form of wind, temperature and precipitation. Where other factors are kept constant, atmospheric (climate) energy correlates strongly with agricultural performance. Climate energy determines the crop type and the ecosystem economy. The observed stochastic behavior of temperatures and rainfall is worrisome and its entry point the economy deserves some investigation. It is known that human beings are at the center of the causes, effects and adaptations behavior to the changing cycles of climate. Without empirical investigation, it is difficult to generalize the exact degree of influence exerted by stochastic energy in the overall livelihood performance in terms of GDP.

Apart from mitigation, collective (macro) approach to adaptation would represent the most effective strategy to first, protect vulnerable populations already experiencing adverse effects of climate change and secondly, protect all people in the future generations. Therefore, collective (macro) approach to adaptation to existing climate extremes is essential for all nations. Social scientists and the policy-making community have begun to explore potential economic consequences of climate change, especially for developing nations, describing it as a stress factor to economic development, food security and health challenges. Inequality in social and economic capacity to adapt to climate change is emerging as a correlate of widening disparities in wealth, security and opportunities for economic development. Countries with adequate resources have the capacity to adapt to climate change, but the poor countries in the developing world are facing more direct stress and adverse impacts, because they lack necessary technical, monetary and human capacities to deal with climate change risks facing their citizens. Many economic problems in many African states are exacerbated by climate stress. Widespread water stress, prevalence climate related diseases, poor performance of rain-fed agriculture, and low economic productivity are occurring in climate-sensitive economies. Previous works on the micro-economic effects of climate hazards but little or no empirical work on macroeconomic impact of climate related stress at has been reported in Nigeria. For instance, the report of the work done by Emaziye, (2012) as shown in Table 1.0 accentuates climate hazards adversely effects on the economy of farming households heads, such as lost of farm investments (25.08%), lost of income (24.92%) and lost of farms (22.46%).

Table 1. Distribution of Socio-Economic Effects of Hazards of Climate Variability on Rural Farming Households heads in the Niger Delta,Nigeria

Socio-conomic effects	Bayelsa (n=186)	Cross River (n=172)	Delta (n=198)	Ondo (n=183)	Niger Delta (n=739)	Mean % effect
Lost of household properties	20(3.3)	23(4.1)	42(5.7)	65(10.2)	150(5.9)	4.52
Lost of houses	16(2.6)	8(1.4)	20(2.7)	42(6.6)	86(3.4)	3.34
Lost of farms	160(26.5)	103(18.4)	167(22.8)	141(22.1)	511(22.5)	22.46
Lost of investment on farm lands	165(27.2)	164(29.2)	180(24.6	124(19.4)	633(25.0)	25.08
Lost of lives	2(0.3)	4(0.7)	1(0.10)	3(0.01)	10(0.4)	0.30
Lost of income	165(27.2)	161(28.7)	180(24.6)	123(19.3)	629(24.8)	24.92
Lost of roads	28(4.6)	17(3.0)	40(5.5)	23(3.6)	108(4.3)	4.2
Ill health	50(8.3)	87(14.5)	101(13.8)	117(18.3)	349(13.7)	13.72

Figures in parenthesis are corresponding percentage values.
(Source: Emaziye 2012).

Human development impacts will also vary as changes in climate patterns interact with pre-existing social and economic vulnerabilities, but there are several main risk-multipliers for human development reversals that are associated with extreme climate events. One of the most pertinent issues in regards to human development is reduced agricultural productivity. A majority of the world's population officially living in poverty (under US$ 1 per day) depends directly on agriculture for their survival. Climate change scenarios indicate substantial losses in the production of food staples linked to drought and rainfall variation, especially in areas of sub-Saharan Africa, where projected revenue losses due to loss of arable land amount to 26 percent by 2060. Such an impact on agricultural production would directly influence food security, leaving 600 million facing malnutrition by 2080 in addition to predictions that do not take climate change into consideration.

Short-term consequences such as flooding, are often longer, intensified and more frequent, the impact of which is long-felt on a macro economic performance of developing nations. Food production is the critical first step in the food supply chain, and an area that has received extensive research attention. A subset of this involves research on sustainable agriculture. It is at the intersection of sustainable production agriculture and climate systems research that climate stress impacts are likely to be found, although much of what has been written to date on climate impact on agriculture starts from the broader field of production agriculture.

Status of current knowledge indicates that many international research works are focused sometimes on agriculturally specific stories and recommendations (Economics of Climate Adaptation Working Group, 2009), but with little or no emphasis on national aggregate scales. These international reports discuss the multiple impacts, sometimes explicitly excluding impacts of climate stress on Gross Domestic Products of vulnerable developing nations, such as Nigeria.

Case studies must therefore evaluate the economic buoyancy of developing nations under climate stress. Climate change projections and potential impacts on agricultural production have been explored in 15 different scenarios for food security through 2050 in a report from the International Food Policy Research Institute (IFPRI) (Nelson et al., 2010), but national welfare in terms of GDP was left out of such reports.

Previous studies on attributions of a country's climate extremes have produced ambiguous results, possibly due to errors of data types and statistical tools. It is important to accentuate time-frequency domain in the present study, may detect appealing relations that exist between random tendencies of climate variables (temperature and rainfall) and economic buoyancy of nations whose economies are based on agricultural livelihoods.

Increasing frequency of extreme weather events will add to production risks and distortions in economic buoyancy. Existing research is not sufficient to show clear adaptation policies at national level, to soften the negative impact of random cycles of climate variables on macroeconomic buoyancy in Nigeria. New knowledge of impact of temperature and rainfall variation on yields of major commodity crops and livestock species is needed to mitigate the fragile agriculture and risks to food security (Beddington et al., 2011; Easterling et al., 2007).

The scientific literature assessing the impact of climate change on agriculture largely focuses on relatively simple assessments of the impact of changing temperature, precipitation patterns, and CO_2 elevation on crop yield (Parry et al., 2004; Parry et al., 2005; Schlenker and Roberts, 2009), with limited evaluation of adaptive policy responses by government. There has been minimal integration of climate induced economic stressors into macro-economic projections and performance analysis in Nigeria before now. Hence macro-economic responses for adaptation and resilience to climate extremes are often undermined by government. Many trade-offs exist in macro-economic adaptation strategies for climate extremes and economic progress, and these need to be better understood. This study will form a background for developing viable macroeconomic adaptive policies aimed at stabilizing aggregate agricultural output and gross domestic product (GDP), hence it will be very useful for economic planning and policy making for economic development. There is a gap in information on macro-economic risk associated with short and long-terms variability of temperature and rainfall. This study was designed to fill this information gap.

The major objective of this study is to determine the impact of stochastic behavior of climate variables on macro-economic buoyancy in Nigeria. Specifically, the purpose of the study includes:

i) To ascertain the effect of Time scales of climate variables on Aggregate agricultural output and Gross Domestic Product (GDP) in Nigeria
ii) To assess the impact of random cycles of Aggregate agricultural output due to climate shocks on Gross Domestic Product (GDP) (2004-2012).

Materials and Methods

Description of Data

The hypothesis of climate-dependent economy is mostly centered on the time-domain methodologies ignoring frequency-domain. Analyzing the issue in the time-frequency domain, however, may detect many appealing relations that operate exclusively at different frequencies. Frequency, in this regard, is the rate of change of the selected variables over time. It is likely that the link between climate variables and Agricultural buoyancy and GDP may vary across frequencies and time. Such random relationship may provide signals that can provide explanation for unsteady aggregate economic buoyancy. The approach of wavelet, in this regard, proves very useful for its potentiality to decompose the aggregate time series data into different frequency-bands or time scales. The basic wavelets are grouped into two different categories: the long-term wavelets and the shot-term wavelets.

Data Collection Techniques

For the empirical estimation monthly data over the period of 2004 to 2012, of index of agricultural output and temperature and rainfall were utilized so that we have sufficient observations over the period which coincides with the flood era of 2012 in Nigeria. Time series data of climate variables were obtained from Meteorological Centre and outputs of major foodstuffs were collected from Central Bank of Nigeria Annual report over the period January 2004 to December, 2012.

Data Analysis Techniques
Research Hypotheses

The following hypotheses were formulated and tested to guide the study.

H_{O1}: Stochastic tendencies of climate variables do not have significant impact on Aggregate Agricultural Output (AOP) and Gross Domestic Product (GDP) in Nigeria.

H_{02}: Climate-based unsteady Agricultural Output has no significant effect on Gross Domestic Product in Nigeria (2004-2012).

H_{O3}: Time scales of climate variables do not have significant impact on aggregate agricultural output and Gross Domestic Product (GDP) in Nigeria.

Following Gençay et al. (2002), time series data were decomposed on a scale-by-scale (short-term and long-term) basis.

Model Specification

In this study, macro-economic buoyancy was captured using aggregate agricultural output (AOP) and Gross Domestic Product (GDP) as proxy. The relationship between macro-economic buoyancy and climate variables was explicitly captured in the short scale and long scale models:

Short Scale Equations

Model 1: $AOPt = \beta_0 + \beta_1 TEMP_t ST + \beta_2 RAIN_t ST + \mu$. (Equ. 1)

Model 2: $GDPt = \beta_0 + \beta_1 TEMP_t ST + \beta_2 RAIN_t ST + \mu$ ..(Equ. 2)

Long scale Equations

Model 3: $AOPt = \beta_0 + \beta_1 TEMP_t LT + \beta_2 RAIN_t LT + \mu$ ...(Equ. 3)

Model 4: $GDPt = \beta_0 + \beta_1 TEMP_t LT + \beta_2 RAIN_t LT + \mu$. (Equ. 4)

Where:

AOP_t = Aggregate Agricultural Output

GDP_t = Gross Domestic Product

$TEMP_t ST$ = Short scale Temperature influence

$TEMP_t LT$ = Long scaleTemperature influence

$RAIN_t ST$ = Short scale rainfall influence

$RAIN_t LT$ = Long scale rainfall influence

β_0 = Intercept Term

$\beta_{1-}\beta_3$ = Parameter coefficients

μ = Error Term.

Short scale is defined as the period of 5years (i.e. 2008-2012). Long scale is defined as the period of 9 years (i.e. 2004-2012). Also, E- view software was used to analyze time scale relationship between Gross Domestic Product (GDP), Aggregate Agricultural Output and climate variables (Temperature and Rainfall). Data on both variables were obtained from Central Bank of Nigeria (CBN) CD-ROM (2012).

Results and Discussion

Econometric Models

The results indicate that random cycle of extreme atmospheric energy correlates significantly with distortions in macroeconomic buoyancy, especially, at lower time scales (0.83) but weaker (0.32) with longer scales. Therefore, Aggregate Agricultural Output (AOP) and Gross Domestic Product were confirmed to be a function of time scales variability of atmospheric energy.

As shown in Equation1, the regression coefficients of temperature and aggregate agricultural output were found statistically significant and contributed to the Gross Domestic Product in Nigeria over the period under review.

In regression analysis, value of variance of dependent variable is explained on base of independent variable, called Explained Variance (R^2). R^2's value was 0.9 for model 1. It means that 90% of changes in GDP dependent on temperature and aggregate agricultural output. For heteroscedasticity test, autocorrelation was also tested using Durbin–Watson test. Durbin–Watson value for model 1 was found to be 2.3 indicating that there is no autocorrelation in the model.

Time Scales Effect Of Climate Shocks (Temperature And Rainfall Variability) On Macroeconomic Buoyancy In Nigeria

Short Scale Relatioinship Between Climate Variables and Macroeconomic Buoyancy in Nigeria (2008-2012).

The short scales effect of variability of climate variables (temperature and rainfall) on Macroeconomic buoyancy Aggregate Agricultural Output (AOP) and Gross Domestic Product (GDP) of Nigeria is presented in equation 5 and equation 6, respectively:

$AOPt = 0.47 - 0.187TEMP_t ST + 0.13RAIN_t ST + \mu$. (Equ.5)
(1.84)NS (11.98)** 1.67)NS

$GDP_t = 0.98 + 0.0008RAIN_t ST – 0.08TEMP_t ST + \mu$ ..(Equ.6)
(1.13)NS (0.31) NS (3.23)**

$R^2 = 98\%$

$F (3,6) = 93.73$

*= Significant at 5%

** = Significant at 1%

$GDP_t = 0.98 + 3.69AOP_t ST + \mu$ (Equ.7)
(1.13)NS (10.88)**

The figures in parenthesis directly below the coefficients are the corresponding t-values.

The model shows the cumulative effect of climate shocks on macroeconomic buoyancy in the short run. In equation 5 and equation 6, among the climate variables included, temperature (0.187) was found to be the most important variable that influenced aggregate agricultural output and GDP. This implies that a 1% increase in temperature over a period of 5years will reduce agricultural output by 0.87%. The impact of temperature variability is 0.71. Therefore 1% change in temperature variability will lead to 0.71% distortions in GDP. Aggregate agricultural output with 0.54 is the second important factor on yield.

Long Scale Relationship between Climate variables and Macroeconomic Buoyancy in Nigeria

Equation or Model 5;

$AOPt = 0.37 + 0.002RAIN_tLT - 0.63TEMP_tLT + \mu$ ....(Equ. 8)

(1.20) (0.99) (2.75)**

$GDP_t = 0.69 + 0.068RAIN_tLT - 0.82TEMP_tLT + \mu$ ....(Equ. 9)

(0.57)NS (1.12)NS (1.97)*

*= Significant at 5%

** = Significant at 1%

NS = Not significant

$R^2 = 98\%$

$F (3,6) = 97.11$

The model in equation 5 captures long run effect of temperature and rainfall on aggregate agricultural output (AOP) in Nigeria (2004-2012). The result shows that aggregate agricultural output correlates positively, but not significantly with annual rainfall in the long run. This implies that within the period under investigation, Agriculture received insignificant influence and support from rainfall.The finding of the study further reveals that aggregate agricultural output correlates negatively and significantly (P<0.05) with temperature variation in the long run.

This finding could be due to the fact that rainfall effect on aggregate agricultural output could be moderated or reduced by artificial irrigation in the long run particularly in the northern part of Nigeria where agriculture is practiced on a large scale. This is not the case with temperature variability; hence it can significantly affect agricultural output in the long run.

Long Scale Relationship between Aggregate Agricultural Output and Gross Domestic Product (GDP) in Nigeria (2004-2012).

$GDP_t = 0.002 + 0.92AOPtLT + \mu$ ....Equ. (10)

(0.9)NS (11.20)**

*= Significant at 5%

** = Significant at 1%

NS = Not significant

The result shows that the mean aggregate agricultural output (2004 -2012) is 8,044,383MT and coefficient of variation (c.v) of aggregate agricultural output is 36%.The result shows that aggregate agricultural output correlates positively and significantly with GDP in the long run (0.92) at (P< 0.01). This result indicates that higher agricultural output on the aggregate could translate to higher Gross Domestic Product (GDP) of Nigeria. This further implies that whatever affects aggregate agricultural output positively could also affect Gross Domestic Product (GDP) of Nigeria. This finding could be due to the fact that the livelihood of majority of people in Nigeria, particularly, the rural people are agriculture-based.

Impact Analysis of Climate Variables on Agricultural Output and Gross Domestic Product

i. Variation in Aggregate Agricultural Output with respect to variation in temperature = Aggregate Agricultural Output variance/temperature variance = 0.36/0.019 = 18.95. Variation in temperature created an impact of 18.95% on Aggregate Agricultural Output.
ii. Variation in Aggregate Agricultural output with respect to variation in rainfall = Aggregate Agricultural Output variance/rainfall variance = 0.36/0.15 = 2.4. Variation in rainfall created an impact of 2.4% on Aggregate Agricultural output.
iii. Short run Variation in Gross Domestic Product (GDP) with respect to variation in Agricultural output = GDP variance/AOP variance = 0.33/0.36 = 0.92. Short run variation in Agricultural output created an impact of 0.92% on Gross Domestic Product (GDP). The relatively low impact 0.92% created by AOP on GDP could be attributed firstly, to the fact that adverse effect of stochastic cycles of atmospheric energy on Aggregate Agricultural Output must have reduced its contribution to GDP for the period. Secondly, GDP does not only respond to Agricultural output but to the output from other sectors such as mining, oil and gas, banking, manufacturing, etc.

iv. Short run variation in Gross Domestic Product with respect to variation in temperature GDP variance/temperature variance = GDP variance/temperature variance = 0.33/0.019 =17.37. Short run variation in temperature created an impact of 17.37% on Gross Domestic Product.

v. Short run variation in Gross Domestic Product with respect to variation in rainfall = GDP variance/rainfall variance = 0.33/0.15 = 2.2. Short run variation in Gross Domestic Product with respect to variation in rainfall created an impact of 2.2%.

On the whole, short run variation in temperature created the highest impact on Aggregate Agricultural output and Gross Domestic Product as distinct from rainfall which created less contribution to Aggregate Agricultural output and GDP. This implies that temperature variation adversely affect both physical environmental condition that supports production and human systems that generate the capacity for production. Relatively high temperature has the tendency to reduce land and labour productivity. Aggregate agricultural growth will occur with country-wide innovation or adaptive strategies that can boost both land and labour productivity in agriculture under climate stress. This result is in agreement with Kwadwo (2009), who earlier recommended the involvement of farmers in information networking on nation-wide scale. Climate-based knowledge creation, accumulation, sharing and utilization by farmers will build their capacity to adapt to climate stress in Nigeria.

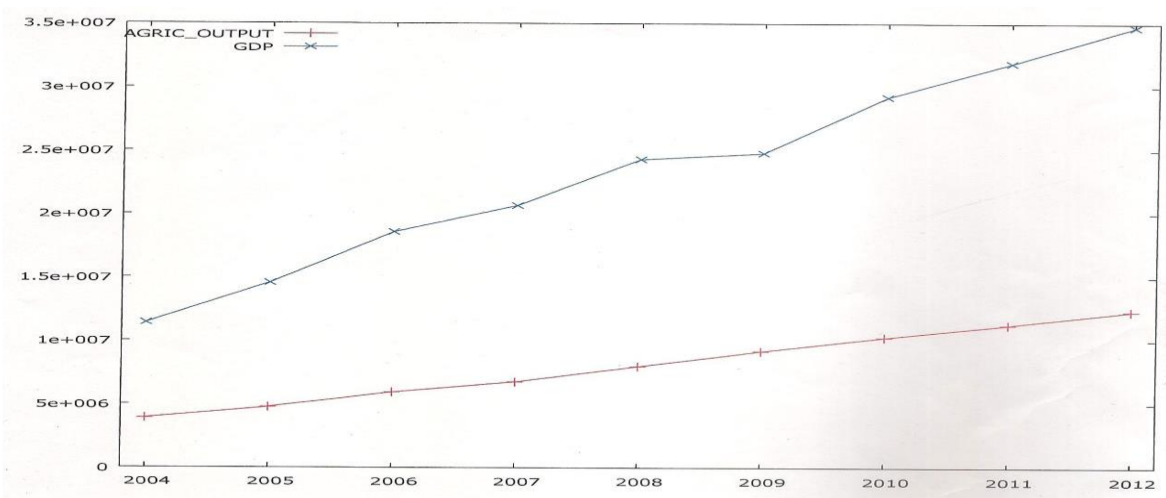

Figure 1. Relationship between aggregate agricultural output (AOP) and Gross Domestic Product (GDP)

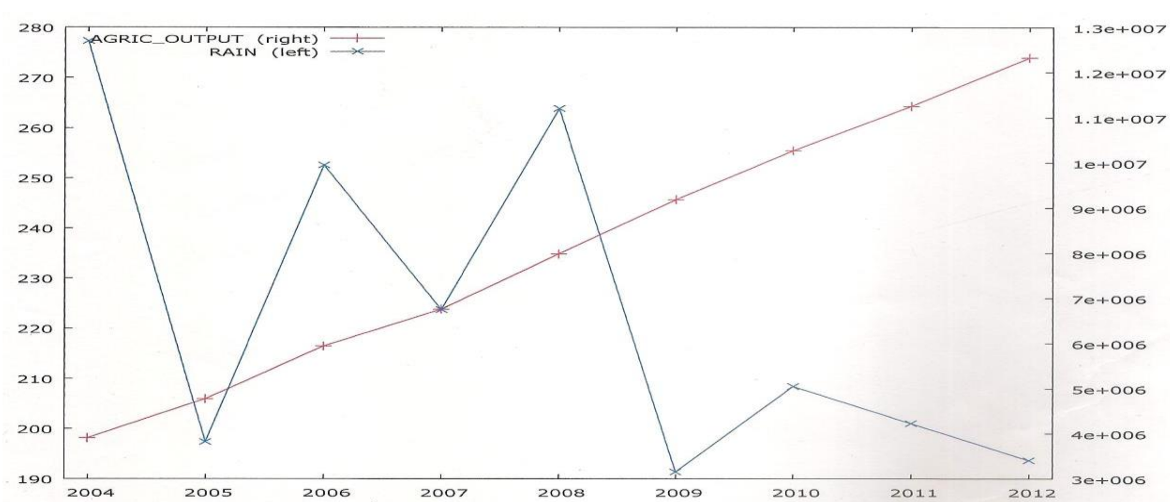

Figure 2. Relationship between agricultural output and rainfall variation

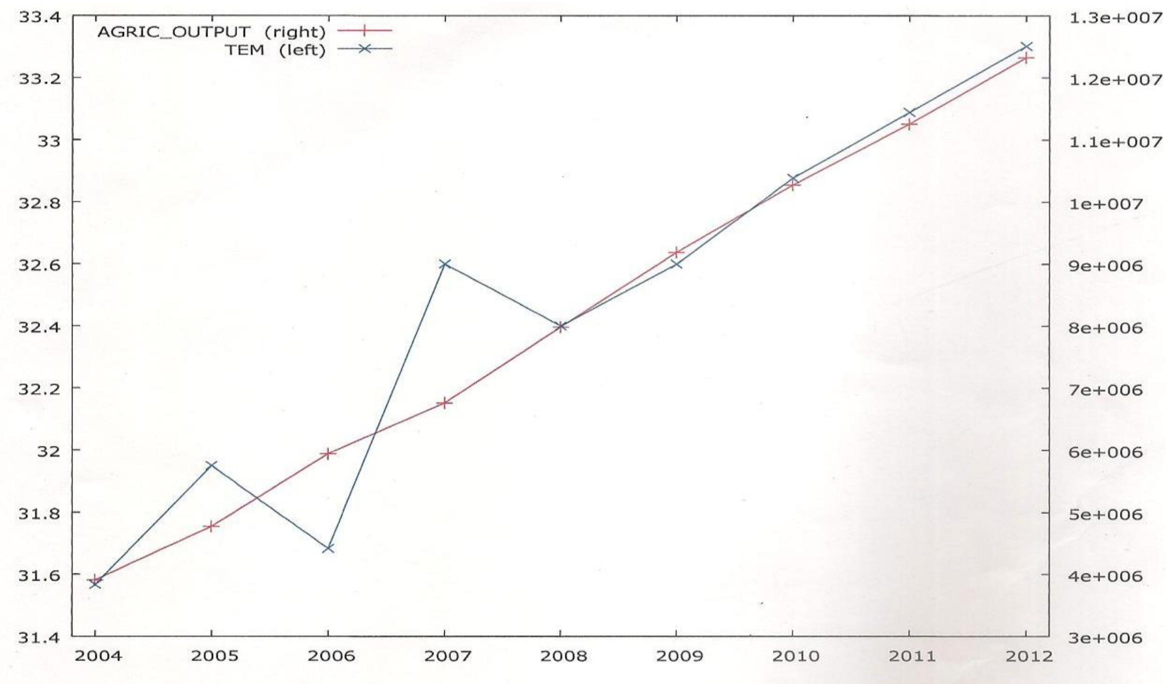

Figure 3. Relationship between agricultural output and temperature variation

Implications of effect of Stochastic Cycles of Climate Variables on the Macro-economic Buoyancy of Nigeria.

Macro-economic implications of models are not well understood until the theoretical bases are made explicit. This study provides sufficient theoretical and empirical evidences of stochastic cycles of extreme climate change event and its impact on the economy of Nigeria. No doubt extreme climate change event through impact on livelihood has introduced distortion/shocks into the economic buoyancy of Nigeria. Gross Domestic Product (GDP) is generated from aggregate agricultural livelihood activities of the people. Any climate stress on the agricultural livelihoods has a reverberate effect on GDP. Economic theory has it that GDP is an index of the performance of the economy. Agriculture-based economies that are vulnerable to extreme climate change events will definitely suffer a decline in performance through loss of productivity. There is the likelihood that emerging economies such as Nigeria may be submerged by the impact of extreme climate events unless macro-economic policies on adaptation are formulated and implemented (Achoja and Adjekota, 2013).

Conclusion and Recommendations

This study provides sufficient theoretical and empirical evidences of stochastic cycles of extreme climate events and its impact on the economic buoyancy of Nigeria through short term time scale impacts on livelihoods. Climate change will entail multiple exposures to overlapping and interacting stressors on the economy. Clearer scenarios are needed for how risks to those most vulnerable economies to atmospheric stressors can be reduced. This implies that temperature variation could inhibit both physical environmental condition that supports production and human systems that generate the capacity for production. Relatively high temperature has the tendency to reduce the productivity of agricultural economy of a nation. A comprehensive assessment of the points or thresholds at which the economy is most vulnerable to extreme distortion of atmospheric energy, and the impacts of this vulnerability on food and welfare security, is needed (Achoja and Adjekota, 2013).

Arising from the findings of this study, it is recommended that:

1. Short run swift adaptive response measures for climate extremes was recommended to enhance macro-economic stability in Nigeria.
2. The overall performance of the farmers whose livelihood is greatly dependent on

agriculture should be enhanced to boost the Gross Domestic Product (GDP) of the nation.

3. Macro-economic policies should be put in place to mitigate climate change. In a situation where there is a boom in agricultural output as a result of the climate variability, government should introduce measures to keep reserves and regulate the price of agricultural commodities so that farmers do not suffer much loss of income. On the other hand, where there is shortage of food stuff as a result of climate variability, the government should also introduce pric control measures to reduce the effect of the scarcity and eventual high price on the welfare of consumers of agricultural commodities.

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