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Coffee Output Reaction to Climate Change and Commodity Price Volatility: The Nigeria Experience

Anthony Oko-Isu[1*], Agnes Ugboego Chukwu[2], Ofoegbu Grace N.[3], Ololo Kennedy[4], Tobechi Agbanike[5], Lasbrey Anochiwa[5], Nkechinyere R. Uwajumogu[5], Micheal Enyoghasim[5], Okoro Uzoma Nnaji[6], Igberi Christiana Ogonna[1]

1. Faculty of Agriculture, Alex Ekwueme Federal University Ndufu-Alike, Ikwo, Ebonyi State, Nigeria; aokoisu@gmail.com (A.O.-I.) igberitina@yahoo.com (I.C.O)
2. College of Management Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria, chukwuagnes@gmail.com (A.U.C)
3. Department of Accountancy, University of Nigeria, Enugu Campus grace.ofoegbu@unn.edu.ng, (O.G.N)
4. Department of Sociology/Psychology, criminology and security studies, Alex Ekwueme Federal University Ndufu-Alike, Ikwo, Ebonyi State, Nigeria; kenololo@yahoo.com (O.K)
5. Department of Economics and Development Studies, Alex Ekwueme Federal University Ndufu-Alike, Ikwo, Ebonyi State, Nigeria; tobechi_agbanike@yahoo.co.uk (T.A.); lanochiwa@yahoo.com (L.A.); nkechinyereuwajumogu@gmail.com (N.R.U.); mic_martserve@yahoo.com (M.E.)
6. Heritage Bank Plc Umuahia Branch; uzoma.okoro@hbng.com (O.U.N)

[*]Correspondence: aokoisu@gmail.com or anthony.oko-isu@funai.edu.ng

Abstract: Empirical evidence is lacking on the nexus between coffee commodity output, climate change and commodity price volatility of Africa's most populous country, Nigeria and other developing countries. To fill this gap, this study analysed the reaction of coffee output to climate change and commodity price volatility. We used secondary data from 1961 to 2015 from reliable sources for Nigeria. The study adopted GARCH, ARCH and FMOLS in analysis of coffee output reaction to climate change and commodity price volatility. The findings show that coffee output in Nigeria is influenced by climate change and the international commodity price of coffee. The study demonstrates the potential benefits of improving coffee output and export through climate mitigation and adaptation measures and revival of Agricultural Commodity Marketing in Nigeria and other developing countries.

Keywords: Coffee Output; Climate Change; Commodity Price Volatility; GARCH; ARCH; FMOLS

Introduction

The World Bank Group (WBG) 2018 reports that Africa's food market, valued at about US$ 313 billion a year in 2013, could triple by 2030, with investments in infrastructure, smart business and

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trade policies and a dynamic agribusiness sector linking farmers with consumers in growing urban areas. This aligns with African Development Bank (AfDB) report of 2015 that, Africa is at the high point of its development fortune and enjoying its strongest growth in recent times, put at an average of 5–6 per cent in the last 40 years, with progress made on some of the Millennium Development Goals (MDGs) (African Development Bank (AfDB), 2015). This growth has not translated into improved food security and well-being for all Africans. Therefore, agribusiness small and medium enterprises (SMEs) are important for economic development with high potentials for employment generation, food security, foreign exchange earnings and poverty reduction. It is also critic[i]al in linking smallholder producers to national markets, meet food demand and create tomorrow's jobs (World Bank, 2018). These potentials have remained largely untapped which has led to the dwindling performance of the agricultural sector both domestically and in international trade over years. Nigeria reported to be the poverty capital of the World, faced with an increasing population, heavy dependence on import and reliance on crude oil earnings needs to find a solution on how to tap the potentials and solve her problems.

More so, coffee like other tree crops represent one group of agribusiness that merit special attention for climate change adaptation planning as they have a series of traits that make them particularly susceptible to climate change (Akinbola, Adedokun and Nwosa, 2015). Coffee is an important tree crop capable of being harnessed by Nigeria as an important green investment option as Nigeria is the most populous black nation in the world with a massive landmass and very young population but not mentioned in the major exporters of coffee (International Coffee Organization (ICO), 2019).

However, the so-called 'coffee crisis', provoked by the breakdown of the International Coffee Agreement in 1989, triggered a dramatic drop of international prices in the late 1990s (Petchers and Harris, 2008). Prices continued to fall in the first years of this century, and although these were reversed from 2005, reaching a maximum in 2011 (above US$ 300 per pound), by November 2013 they had fallen again to the level of US$ 123 per pound. Price volatility – which has been shown to be particularly pronounced in Guatemala (ICO, 2011) – has wreaked drastic negative impacts on small producers in many developing countries (ICC, 2003; Ortiz-Miranda and Moragues-Faus, 2015). Ironically, the disproportionate effects of the price volatility are mainly on the marginalized populations, especially, women and youths. According to FAO (2011), the roles of women differ within and between countries and have become more dynamic in numerous parts of the world. AfDB (2014) noted that 70 per cent of Africa's smallholder farmers are women, and are responsible for more than 90 per cent of Africa's agricultural production (Ayodeji, Akogun, Adebayo, Shaba, Nwojo, Sanusi and Hamdalat, 2017).

The macroeconomic impacts of commodity prices are important because they affect the level of per capita income, which ultimately is a key determinant of living standards for individuals and families. Generally speaking, high international prices for food commodities benefit countries that export those products, while low prices benefit importing countries. In the longer term, however, higher prices could cause some importing countries to invest in their agriculture and reduce imports, or even become exporters (FAO, 2011).

To the best of our knowledge, no information exists on the reaction of coffee output in Africa to climate change and commodity price volatility. This study therefore was conceived in order to showcase the past, present and predict the future of coffee as an agribusiness option worthy of investment in Africa's most populous nation.

Methodology

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The study area is Nigeria. The Federal Republic of Nigeria is in West Africa between Latitudes 4^0 and 14^0 North and between Longitudes $2^0 2^1$ and $14^0 30^1$ East. To the North, the country is bounded by Niger Republic (1497km) and Chad (853km) to the West by Benin Republic (773km) to the East by Cameroon Republic (1690km) and to the South by Atlantic Ocean. Nigeria has a land area of about 923,769km^2 (FOS, 1989), a North South length of about 1450km and west east breath of about 800km with only 50% of the land proportion presently cultivated. Its total land boundary is 4047km while the coastline is 853km. Irrigation potential estimates in Nigeria vary from 1.5 to 3.2 million ha. The latest estimate gives a total of about 2.3 million ha, of which over 1 million ha are in the north (World Bank, 2014; FAO, 2009).

Nigeria is made up of 36 states and the Federal Capital Territory located in Abuja and enjoys the humid tropical climate with two clear identifiable seasons, the wet and dry seasons. The climate condition varies among regions: equatorial in the South, tropical in the centre and arid in the North. Annual rainfall is between 2000 – 3000mm in a year characterized by high temperatures and relative humidity. Nigeria has four agro-ecological zones with rainfall along the South-North gradient. It is a country of marked ecological diversity and climatic contrast. The lowest point is the Atlantic Ocean at sea level of 0m, while the highest point is the Chappalwaddi at 2,419m (FAO, 2009).

Nigeria has a population of over 173.6 million people (NBS, 2013), with diverse biophysical characteristics, ethnic nationalities (more than 250), agro-ecological zones and socio-economic conditions (FAO, 2009; NIMET, 2008). Popular indigenous languages are Igbo, Hausa and Yoruba while English language is the official language. Farming is the predominant occupation of the people; about half of the working population is engaged in agriculture, majority of who are small holder farmers. Cocoa, Coffee, Oil Palm and rubber are among the major tree crops grown in Nigeria.

The country is faced with an economy characterized by an unstable exchange rate and ecosystems being battered by global warming, while excessive flooding during the past decade has hurt farming in coastal communities and desertification is ravaging the Sahel. Other environmental issues affecting the country include soil degradation, rapid deforestation, water pollution, desertification, oil spill affecting water, air and soil, loss of arable land and rapid urbanization.

Sources of Data

This study was based on time series data obtained from various sources spanning from 1961 to 2015. The monthly national data on climatic variables, output of coffee as well as international commodity prices of coffee tree crop were collected. The sources of the data collected include various publication editions of the National Bureau of statistics (NBS) and Central Bank of Nigeria (CBN) statistical bulletins for data on exchange rate, interest rate with rate of inflation, exports, gross domestic product (GDP) and imports. Nigerian meteorological agency (NIMET), Food, Agriculture Organization (FAO) statistical website of United Nations (UN) and the World Bank climate data for commodity prices, rainfall, temperature and yield of coffee crop.

Method of Data Analysis

Data for the study were analyzed using both descriptive and inferential statistical tools. To achieve objectives, graph form of descriptive statistics, the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) and Autoregressive Conditional Heteroscedasticity (ARCH) models

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with the Fully Modified Ordinary Least Square (FM-OLS) approach were employed. The hypothesis however, was tested with the use of Pair wise Granger Causality approach.

Volatility test

In literature, various measures of commodity price volatility have been employed to examine the variability of pair-wise cross-country commodity prices based on the observation that commodity price time series are typically heteroscedastic, leptokurtic and exhibit volatility clustering- that is, varying variance over a specified period of time (Kenen and Rodrik, 1986, Bailey *et al*., 1986; Peree and Steinherr, 1989; Cote, 1994; McKenzie and Brooks, 1997). On the basis of this and in line with the research objectives, this study examined the extent of coffee commodity price volatility between 1961 and 2015. Like other empirical studies, the Autoregressive Conditional Heteroscedasticity (ARCH) model introduced by Engle (1982) and the generalized ARCH (GARCH) model by Bollerslev (1986) were used to capture the extent of coffee tree crop commodity prices volatility in Nigeria during the period of study.

The choice of these models were based on their empirical use in the various areas of econometric modeling, especially in financial time series analysis (Yinusa, 2008; Akpokoje, 2009; Olowe, 2009) and their approaches in modeling financial time series with an autoregressive structure in that heteroscedasticity observed over different periods may be autocorrelated.

In developing an ARCH model, two distinct specifications were considered - one for the conditional mean and the other for conditional variance. Generalizing this, the standard GARCH (p,q) specification is expressed in implicit form as:

$$y_t = \alpha + \sum_{i=1}^{k} n_i x_{t-1} \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

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Where;

y_t = measure of commodity price volatility at time t,

α = mean,

x_{t-1} = exogenous variables,

ε_t = error term

$$\delta = \sqrt{\frac{1}{N}\sum_{i=1}^{k}(x_i - \bar{X})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where;

δ = variance,

x_i = mean,

$\bar{X}$ = standard deviation

$$\delta t^2 = \omega + \sum_{i=1}^{p} \alpha_i\, \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i\, \delta_{t-i}^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where;

δt^2 = conditional variance,

P = order of the GARCH,

δ_{t-i}^2 = the GARCH term

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The mean equation given in equation (1) was expressed as a function of a constant α-(taken as mean if other exogenous variables were assumed to be zero), exogenous variable(s) x_{t-1}-(majorly in Autoregressive (AR) structure of order k) and with an error term ε_t. Note that y_t was considered a measure of commodity price volatility at time *t*. Since δ_t^2 was the one period ahead forecast variance based on past information, it is called *Conditional Variance*. Equation (3) expresses the normal distribution assumption of the error term. The conditional variance equation specified in (3) represents a function of three components: the mean ω; the information on volatility from the previous period, measured as the lag of the squared residual from the mean equation: ε_{t-i}^2 (the ARCH term); and the last periods forecast variance: δ_{t-i}^2 (the GARCH term).

In equation (1), the k is the order of the AR term, while in Equation (3), the p is the order of the ARCH term and q is the order of the GARCH term. According to Gujarati (2004), a GARCH (p,q) model is equivalent to an ARCH (p+q), that is, in our specification ARCH (k), where k=p+q. for instance, a standard GARCH (1,1) refers to the presence of a first-order ARCH term (the first term n parentheses-p, lagged term of the conditional variance).

For the purpose of this study, the presence of volatility clustering was determined by the significance of the lagged volatility series parameters-y_t. While the degree of extent of volatility in the commodity price was determined by the autoregressive root, which governs the persistence of volatility shocks, and thus was the sum of $\alpha+\beta$ and the indication of the degree of volatility was as follows:

If $\alpha+\beta$ is between 0.51 – 1 or =1(i.e. greater than 0.51 to 1 or equal to 1) it indicates that volatility is present and persistent;

If $\alpha+\beta > 1$ (i.e. greater than 1) it indicates that there is overshooting of volatility

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If $\alpha+\beta < 0.5$ (i.e. less than 0.5) it indicates no volatility.

Baseline Model Specification

The baseline analytical model for the study is specified as follows:

$Y_t = \alpha + \beta_1 CM_t + \beta_2 CP_t + \beta_3 (CM \times CP)_t + U_t$ ………………………………………. (4)

Where;

Y_t = Tree crop yield at time t

CM = Climate change at time t

CP = Commodity price change at time t

$(CM \text{ x } CP)_t$ = interaction between CM and CP at time t and

μ_t = other unobserved variables

The FM-OLS regression approach

The FM-OLS regression approach used following Philips and Hansen (1990), is specified below;

Yit = f (CPit, Tt, P, IR, TO, ER, CMxCP, Σt) …………………………………… (5)

Where

Yit= yield for crop i at time t (tons/hectare),

CPit= Coffee commodity price at time t (U.S $),

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T = mean annual temperature (^{0}C),

P= total annual rainfall (mm),

IR = total annual Inflation rate (%),

TO = Trade openness (%),

ER = Exchange Rate (~~N),~~

CMxCP = climate variables x coffee commodity price at time t (U.S $),

Σt = error term

And

Pit = f (CPit, Tt, P, IR, TO, ER, CMxCP, Σt) ---------------------------------- (6)

Where;

Pit= yield for coffee crop at time t (tons/hectare),

CPit= Coffee commodity price at time t (U.S $),

T = mean annual temperature (^{0}C),

P= total annual rainfall (mm),

IR = total annual Inflation rate (%),

TO = Trade openness (%),

ER = Exchange Rate (~~N),~~

CMxCP = climate variables x commodity price of crop I at time t (U.S $),

Σt = error term

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The Granger causality test model

The Granger causality test, according to Granger (1969), used is specified thus;

$W_t = \varepsilon^n_{y-1}\ \alpha_1\ Z_{y-1} + \varepsilon_j^n\text{-}i\beta w_{y-1} + u_{it}$ ……………………………………………… (7)

$Z_t = \varepsilon^n_{\ p-1}\ \alpha_1\ Z_{t-1} + \varepsilon_{j-1}{}^n\ d_1 w_{t-1} + u_{2t}$ ……………………………………………… (8)

Where

W_t = yield for each of coffee tree crop (tons/hectare),

Z_t = commodity price for coffee tree crop (U.S $),

$_{t-1}$= lag variables,

α_1 and β_1 = parameters to be estimated,

U_{1t} and U_{2t} = error terms

Estimating Trade Openness

The trade openness data was gotten from the trade openness Index which is an economic metric calculated as the ratio of country's total trade, the sum of exports plus imports, to the country's gross domestic product.

Trade Openness = $\frac{\text{Exports+Imports}}{\text{GDP}}$ .... (9)

The interpretation of the Openness Index is that the higher the index, the larger the influence of trade on domestic activities and the stronger the country's economy.

Results and Discussion

Trend of coffee tree crop commodity price, production and yield from 1961-2015

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Considering the international monthly commodity prices of coffee tree crop for the 648 months (1961-2015), there has been considerable variability and instability of the prices of the commodity. As shown in Figure 1, the general trend pattern is characterised by sharp growth and also sharp decline for the time period under study. Between 1961 to 1972 coffee recorded a somewhat similar pattern in its commodity price which was accompanied immediately by a rapid growth from 1975 to 1978 followed by a sharp fall thereafter. It was also observed from Fig. 1 that the upward trend did not characterize the whole period but rather a zigzag trend. In fact, there were steady fluctuations in commodity prices of the selected export tree crops from 1961 to 2015 as shown in Figure 1. Between 1975 to 1978 there was a sharp increase in coffee commodity price from below $2/kg to over $5/kg followed by a decline from 1978 and another sharp increase to its peak price of $5.98/kg recorded in 2011.

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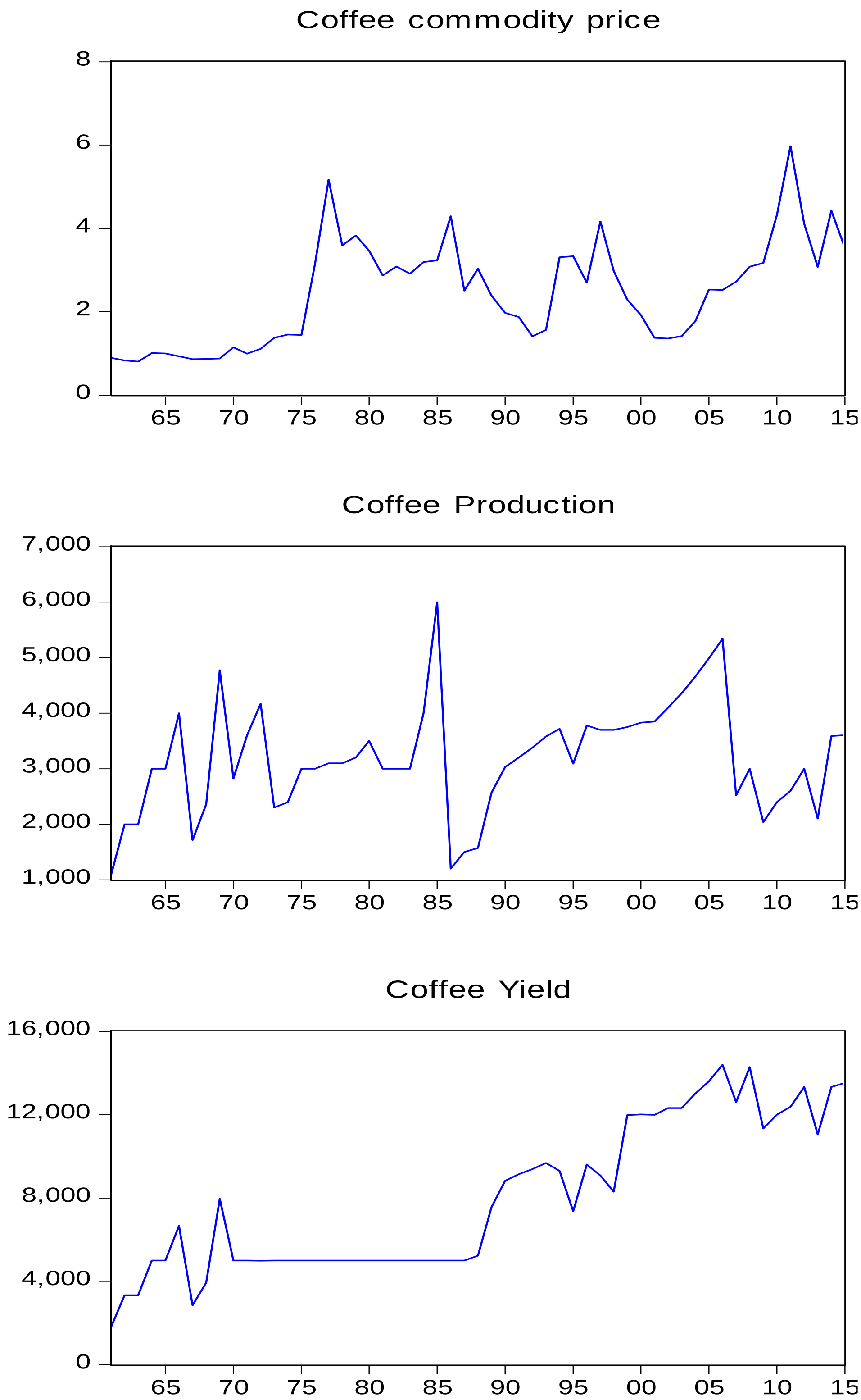

Figure 1: **Trend of coffee tree crop commodity price, production and yield from 1961-2015**

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The graph of trend of coffee tree crop yield (Tons/Ha) as also shown in Fig.1 reveals gradual fluctuations in coffee yield. Coffee yield trend was observed to show fluctuating trend but a steady yield value of 5000Tons/ha was noticed from 1973 to 1983, and a gradual increase to 5233Tons/ from 1984 to 14,394Tons/ha in 2006. The figure shows that the production of coffee showed a somewhat insignificant unstable trend of 4,000tons in 1966 to 6,000tons in 1985 and down to 3,604tons in 2015.

Determination of the time series properties of data employed for analysis

The properties of the time series data used for the analysis were tested. Phillips-Peron (1988) test (hereafter PP) was used in determining the stationarity of the variables under consideration and the results were presented in Table 1.

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 macroeconomic data emanating from Africa (Yusuf and Yusuf, 2007). On application of PP, test variables attained stationarity at level and also after differencing once and thus, one may conclude that there is a mixed order of integration in the data. Stationarity is confirmed when the test statistic is greater that the critical value in absolute terms.

From Table 1, the entire test variables for examining coffee output (yield and production) reactions to climate change and commodity price volatility were stationary at level and after first differencing for some on the basis of the PP probability tests. As such, one could reject the null hypothesis of non-stationarity. The occurrence of unit roots at level in the price data generation process of the commodity gives a preliminary indication of shocks having permanent or long

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lasting effect, thus not making it easy for traditional price stabilisation policies common in African countries to survive (Cashin *et al*. 2004).

Table 1: Unit Root Test Result

	Phillips-Perron Test		
Variable	**Level**	**1st Difference**	**Order of integration**
Climate change			
Rainfall	-5.045133 (0.0001)		I(0)
Temperature	-4.260020 (0.0013)		I(0)
Commodity prices			
Coffee	-2.565541 (0.1064)	-8.338275 (0.0000)	I(1)
Output (production)			
Coffee	-5.406997 (0.0000)		I(0)
Output (Yield)			
Coffee	-2.724048 (0.0766)		I(0)
Others			
Real Exchange rate	1.310611 (0.9984)	-6.287971 (0.0000)	I(1)
Trade openness	-3.007864 (0.1396)	-9.084742 (0.0000)	I(1)
Inflation rate	-3.243140 (0.0228)		I(0)

Source: E-views 9 Researchers' calculations output result from FAO, WBG, NBS, CBN, ICO, NIMET data

Note: Values in parentheses are probability values.

Volatility test for coffee commodity price

Results for the ARCH test for coffee commodity price are presented in Table 2. The Engle's LM test indicates that there are ARCH effects in coffee commodity price. The F-statistic value is significant at the 0.01 probability level and this implies that there is presence of ARCH meaning that there is also presence of heteroskedasticity in the residual.

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Table 2: Heteroscedasticity Test of the Residuals for coffee commodity price
Heteroskedasticity Test: ARCH

F-statistic	4262.971	Prob. F(1,657)	0.0000
Obs*R-squared	570.9989	Prob. Chi-Square(1)	0.0000

Source: E-views 9 Researchers' calculations output result from FAO, WBG, ICO data

The residual plot as shown in Figure 2 further strengthens and approves the strong presence of ARCH and serious heteroskedasticity in coffee commodity price.

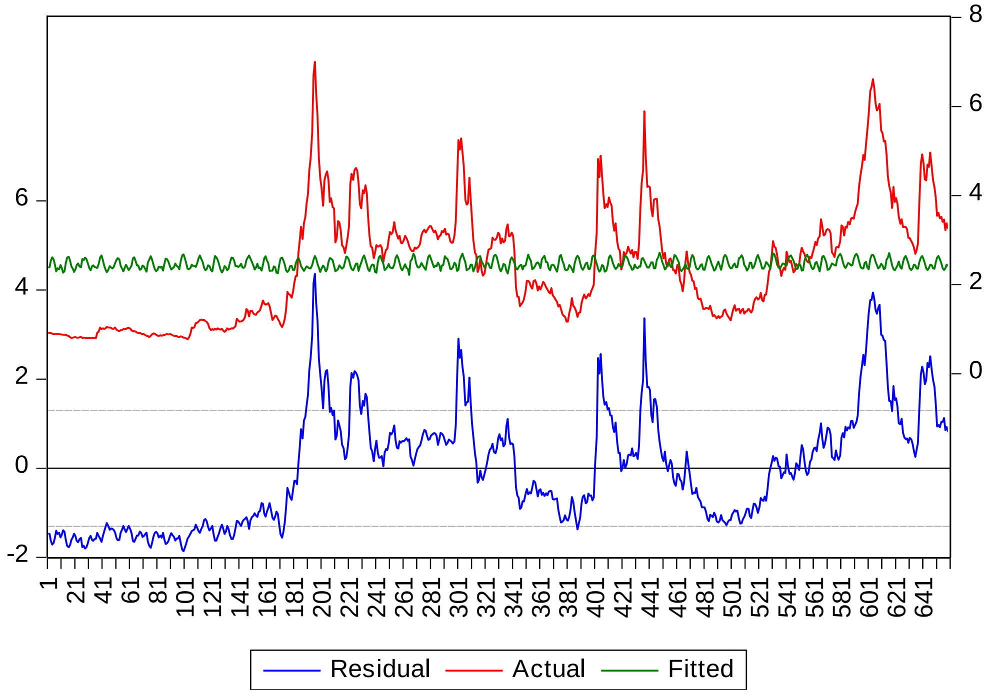

Figure 2: Residuals plot for coffee commodity price
Source: Researchers' calculations output result from Eviews version 9

Table 3 shows the results of volatility test for coffee commodity price using the GARCH approach to verify the presence of volatility in coffee commodity within the period under study. The results show that coffee international commodity price is volatile. The coefficient of the lagged value of coffee commodity price (2.420) had a significant positive relationship with its current value (the dependent variable) overtime for the study period at 1% significant level. In the variance equation,

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the RESID(-1)^2 value of (1.016) confirmed the existence of volatility in coffee commodity price within the period under study.

The implication of the price volatility in coffee commodity price is that, there could be transmission of food price volatility from international to domestic markets. This is in line with the findings of Musunuru (2013).

Table 3: Volatility test for coffee commodity price

GARCH = C(4) + C(5)*RESID(-1)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Intercept	2.420292	0.226604	10.68073***	0.0000
Rainfall	-0.000204	0.000196	-1.041463	0.2977
Temperature	0.010139	0.008497	1.193291	0.2328
Variance Equation				
C	0.036791	0.006877	5.349758***	0.0000
RESID(-1)^2	1.016783	0.120992	8.403714***	0.0000
R-squared	-0.025073	Mean dependent var		2.458062
Adjusted R-squared	-0.028193	S.D. dependent var		1.303766
S.E. of regression	1.322017	Akaike info criterion		2.611361
Sum squared resid	1148.258	Schwarz criterion		2.645394
Log likelihood	-856.7493	Hannan-Quinn criter.		2.624552
Durbin-Watson stat	0.030283			

Source: Researchers' calculations output result from Eviews version 9
***, ** significant at the 0.01 and 0.05 probability levels

Effects of climatic variations and commodity price volatility on the yield and output of coffee output

The parameter estimates of the cointegration regression model (Fully Modified Ordinary Least Squares, FMOLS) applied in analysing the climate variables alongside commodity price and combination of climate variables with commodity price of coffee tree crop to ascertain their effects on coffee output in Nigeria over the period of study are summarized in Table 4.

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The test diagnosis statistics results in Table 4 showed that the test for model fitness gave an R^2 value of 0.94, implying that 94% of the variations in coffee yield were accounted for by variability in the independent variables included in the regression model. The model also had residuals which were normally distributed with a Jarque Bera statistic of 0.100. Similarly, the cointegration test using Engle-Granger Tau statistic recorded a value of -7.076 ($p<0.01$) whereby the null hypothesis which held that "series are not cointegrated was rejected". The series are therefore cointegrated and could be reliably used for forecasting.

It was observed further that temperature, coffee commodity price, trade openness, real exchange rate and climate variables (rainfall and temperature respectively) with commodity price of coffee significantly influenced the yield of coffee in Nigeria at 10%, 5% and 1% level of significance respectively. The slope coefficients of the mentioned variables included were 204.0113 ($p<0.10$); 28474.0 ($p<0.01$), 94.24276 ($p<0.01$), 11.32584 ($p<0.05$), 0.002371 ($p<0.01$) and -95.73726 ($p<0.01$). While it could be inferred from the results that climate variables combined with coffee commodity price together with trade openness and real exchange rate and coffee commodity price significantly determined the variability in yield of coffee over the period of study, temperature and precipitation changes more so do not exert the expected effect on coffee yields.

While temperature increase resulted in increase of yield of coffee during the review period, it was observed that coffee yields however, responded negatively to increase in temperature combined with coffee commodity price in the study. A percentage increase in the volume of temperature resulted in an increase in coffee yield by 204.0113 tons; while a percentage rise in temperature combined with coffee commodity price resulted in a decrease in yield of coffee by 95.73729 tons. The result is inconsistent with the findings of Kanu (2015) Lloh *et al*. (2014) and Ayinde *et al*.

(2013) who had positive and negative coefficients for temperature and rainfall on a similar study in Nigeria.

The caveat that can be deduced from these findings is that other parameters may be needed in explaining yield changes. Sometimes, climate change or variability can result in opportunities for increase in yield or productivity of crops depending on the agronomic requirements of the particular crop under a particular, prevailing climate.

Table 4: Results of FMOLS Parameter Estimates to Model the Effect of Climate Variables, Commodity Price Volatility and Joint Effect of Climatic Variables with Commodity Prices Volatility on Yield of Coffee in Nigeria (1961-2015)

Dependent variable	**Coffee Yield**	
Independent variables	**Coefficient**	**Standard Error**
Intercept	-59997.33 (-2.486005)	24134.030
Trend	129.0227 (5.134969)***	25.126
Rainfall	-0.001484 (-0.617369)	0.002
Temperature	204.0113 (2.638827)*	77.311
Commodity price	28474.40 (3.174368)***	8970.099
Inflation	0.757708 (0.079467)	9.535
Trade openness	94.24276 (3.364582)***	28.011
Real exchange rate	11.32584 (2.095428)**	5.405
Rainfall with commodity price	0.002371 (3.003671)***	0.001
Temperature with commodity price	-95.73729 (-3.297216)***	29.036
R-squared	0.94	
Adjusted R-squared	0.92	
Jarque Bera Statistic	0.100	
Engle-Granger tau-statistic	-7.076***	
Long Run Variance	698472.1	

Remark on Correlogram of Residuals Squared	Not significant at 10%
Mean dependent var	8092.722

Source: output result from Eviews version 9
Note: ***, ** and * = Figures significant at 1%, 5% and 10% probability levels

The indication from the result which showed that the combination of climate variable (temperature) with coffee commodity price exerted a negative significant influence on the yield of coffee in the study implies that, an increase in value of combination of temperature with coffee commodity price was accompanied by a decrease in coffee yield by -95.73729 tons.

Effects of climatic variations, commodity prices volatility and joint effects of climatic variations with commodity prices volatility on coffee production

In Table 5 results of parameter estimates for FM-OLS models used to analyze the effects of climate variables, commodity prices and joint effects of climate variables with commodity prices on production of coffee tree crop in Nigeria from 1961 to 2015 are presented.

The model estimates' diagnosis of the residuals done for coffee production indicated that, the series were cointegrated with Engle-Granger Tau statistics of -6.575 ($p>0.06$) implying that a long run stable relationship does not exist among the series. The model's residuals also exhibited a Jarque Bera statistics of 6.014 implying that the residuals were normally distributed. With the estimated correlogram of the residuals squared significant at 1% it can be concluded that the residuals were not fraught with serious threats of neither serial correlation nor severe muticollinearity in the model. The model also showed a good fit for the R^2 level and thus, implies a good fitting of the model.

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Table 5: Results of FMOLS Parameter Estimates to Model the Effect of Climate Variables, Commodity Prices Volatility and Joint Effect of Climatic Variables with Commodity Prices Volatility on Production of Coffee in Nigeria (1961-2015)

Dependent variable			**Coffee production**	
Independent variables	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Intercept	-1561618. (-1.821641) *	857259.1	-2905.669 (-2.419072) **	1201.150
@Trend	274.5286 (0.341982)	802.757	0.038157 (2.813904) ***	0.014
Rainfall	-0.077223 (-0.959398)	0.081	6.27E-06 (2.093096) **	3.00E-06
Temperature	5805.777 (2.128044) **	2728.222	-1.919630 (-2.466962) **	0.778
Commodity price	905802.5 (2.133219) **	424617.6	-616.4039 (-2.446665) **	251.936
Inflation	434.9243 (1.320889)	329.266	0.002577 (0.054020)	0.048
Trade openness	2280.705 (2.349205) **	970.841	0.062987 (3.438604) ***	0.018
Real exchange rate	567.4082 (2.767124) ***	205.053	-0.331229 (-3.195231) ***	0.104
Rainfall with commodity price	0.175076 (4.080897) ***	0.043	-3.985003 (-1.589991)	2.506
Temperature with commodity price	-3328.699 (-2.426696) **	1371.7	620.0767 (2.456328) **	252.441
R-squared	0.81		0.36	
Adjusted R-squared	0.77		0.21	
Jarque Bera Statistic	3.111		6.014	
Engle-Granger tau-statistic	-7.466***		-6.575**	
Long Run Variance	8.38E+08		0.041624	
Remark on Correlogram of Residuals Squared	Not Significant at 10%		Significant at 1%	
Mean dependent var	272528.900		8.046639	

Source: output result from Eviews version 9

Note: ***, ** and * = Figures significant at 1%, 5% and 10% probability levels

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As can be observed in Table 5, coffee production was significantly determined by six variables which included rainfall (6.27E-06; $p<0.06$), temperature (-1.919630; $p<0.06$) coffee commodity price (-616.4039, $p<0.05$), trade openness (0.062987; $p<0.02$) and temperature with coffee commodity price (620.0767, $p<0.05$). The recorded significant effect of rainfall and combination of temperature with coffee commodity price implied that climate variability is an important factor influencing the production of coffee in Nigeria. It was specifically observed that a percentage increase of rainfall during the period in review resulted in a production increase of coffee by 6.27 tons while, a percentage increase of the combination of temperature with coffee commodity during the period in review resulted in a production increase of coffee by 620.0767 tons. This result demonstrates the influence of climate variables on farmers' decision to produce coffee, showing that weather is important in determining production of coffee in the country.

Amongst the six significant variables, rainfall, trade openness and the combination of temperature with coffee commodity price posed as positive significant determinants of production of coffee in Nigeria over the period of study. The effect implies that rainfall, trade openness and the combination of temperature with coffee commodity are huge determinant factors in coffee production and export. For instance the slope coefficient of rainfall, trade openness and the combination of temperature with coffee commodity in the study showed that a percentage increase in rainfall, trade openness and the combination of temperature with coffee commodity resulted in an increase in production of coffee by about 6.27, 0.062987and 620.0767 tons respectively.

As for temperature, coffee commodity price and real exchange rate, it was found that their significant effects on the production of coffee were negative. It was specifically found that a percentage change in their values resulted in a decrease in coffee production by 1.919630, 616.4039 and 0.331229 tons respectively in the economy during the period in review.

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Test of hypotheses

In Table 6, the results of pairwise Granger causality test on the relationship between coffee tree crop output, climate change variables and coffee commodity price are presented.

Hypothesis one

H_{O1}: There is no significant relationship between the output of selected coffee tree crop, and variation of rainfall in Nigeria

The null hypothesis which held that rainfall did not Granger cause coffee output and vice versa were accepted as their F-Statistic were not significant at any probability level. This enabled us to conclude that, rainfall has no significant relationship with the output of coffee and vice versa.

Hypothesis two

H_{O2}: Variation in temperature has no significant effect on coffee tree crop output in Nigeria

In testing hypothesis two, the null hypothesis that coffee output did not Granger Cause temperature gave an F-Statistic of 3.05113 ($p>0.05$) indicating that we have to reject the hypothesis at a significant value of 10%. This enabled us to conclude that, coffee output influenced the variation of temperature.

It would thus be interpreted that the outputs of coffee in the previous year will transmit information to its producers, marketers or exporters that there would be either glut or scarcity of the product in the present year as its output is associated with variation of temperature degrees. This will in turn, influence the present international commodity prices of these tree crops.

Hypothesis three

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H_{O3}: Commodity price volatility has no significant effect on coffee tree crop output in Nigeria.

The null hypotheses which held that the international commodity prices of coffee did not Granger cause coffee output and vice versa were accepted as their F-Statistic were not significant at any probability level. This enabled us to conclude that the commodity prices of coffee, oil palm and rubber tree crops has no significant effects on the outputs of coffee, oil palm and rubber and vice versa.

Table 6: Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Prob.
Coffee output does not Granger Cause Rainfall	53	0.22433	0.7999
Rainfall does not Granger Cause coffee output		0.19904	0.8202
Coffee output does not Granger Cause Temperature	53	3.05113*	0.0566
Temperature does not Granger Cause coffee output		1.06039	0.3543
Temperature does not Granger Cause D(coffee commodity price)	52	0.04543	0.9556
D(commodity price) does not Granger Cause Temperature		0.38295	0.6840

Note: * = Figures significant at 10% probability levels

Summary of findings

The study examined the response of climate variability, commodity prices volatility and other select macro-economic indicators on output of coffee tree crop in Nigeria from 1961-2015. Descriptive statistics, GARCH and ARCH models and the F-MOLS were analytical tools employed to realize the specific objectives.

The descriptive analysis of trend in commodity prices, yield and production of coffee export tree crop showed there are fluctuations (upward and downward trend) in price, yield and production of coffee tree crop.

In determining the time series properties of data employed, the results of the unit root test by Philip Perron showed a mixed order of integration among the variables employed. That is to say that, some of the variables were non stationary in their level form but became stationary when subjected to first difference.

The result from volatility test shows that there is volatility in international commodity price of coffee. The coefficient of the lagged value of their commodity price had a significant positive relationship with its current value overtime for the study period. The variance equation value of coffee tree crops still confirmed the existence of volatility in their commodity prices within the period under study.

The analysis on the effects of climate variables, commodity price and combination of climate variables with commodity price to ascertain their effects on coffee tree crops yield using FM-OLS showed that the model used had a good fit with their observed R^2 levels and other diagnosis statistics.

Specifically, the yield of coffee showed that it was negatively affected by combination of climate variable (temperature) with coffee commodity price at 1% level of significance and positively affected by temperature, coffee commodity price, trade openness, real exchange rate and combination of rainfall with coffee commodity at 10%, 1% and 5% level of significance respectively.

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Furthermore, coffee production result from the FM-OLS showed that it was positively influenced by rainfall, trade openness and combination of temperature with coffee commodity price at different levels of significance respectively and negatively by temperature, coffee commodity price and real exchange rate also at various levels of significance.

H_{O1}: There is no significant relationship between the output of selected coffee tree crop, and variation of rainfall in Nigeria

The null hypothesis which held that rainfall did not Granger cause coffee output and vice versa were accepted as their F-Statistic were not significant at any probability level. This enabled us to conclude that, rainfall has no significant relationship with the output of coffee and vice versa.

Hypothesis two

H_{O2}: Variation in temperature has no significant effect on coffee tree crop output in Nigeria

In testing hypothesis two, the null hypothesis that coffee output did not Granger Cause temperature gave an F-Statistic of 3.05113 ($p>0.05$) indicating that we have to reject the hypothesis at a significant value of 10%. This enabled us to conclude that, coffee output influenced the variation of temperature.

It would thus be interpreted that the outputs of coffee in the previous year will transmit information to its producers, marketers or exporters that there would be either glut or scarcity of the product in the present year as its output is associated with variation of temperature degrees. This will in turn, influence the present international commodity prices of these tree crops.

Hypothesis three

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H_{O3}: Commodity price volatility has no significant effect on coffee tree crop output in Nigeria.

The null hypotheses which held that the international commodity prices of coffee did not Granger cause coffee output and vice versa were accepted as their F-Statistic were not significant at any probability level. This enabled us to conclude that the commodity prices of coffee, oil palm and rubber tree crops has no significant effects on the outputs of coffee, oil palm and rubber and vice versa.

The test of hypotheses result showed that the null hypothesis which held that rainfall did not Granger cause coffee output and the null hypothesis which held that coffee output did not Granger cause coffee commodity price were accepted. However, the null hypothesis which held that coffee output did not Granger cause temperature was rejected.

Conclusion

Based on the findings of this study, the study concludes that there is therefore need for trade facilitation to reduce inherent risks in agribusiness marketing by re-introducing and re-invigoration of the centre for Agricultural Commodity Marketing (CACMART) by the Government of Nigeria through its institutions.

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