EFFECT OF ENERGY CONSUMPTION ON AGRICULTURAL PRODUCTIVITY IN NIGERIA: APPLICATION OF THE VECTOR ERROR CORRECTION MODEL (VECM)

Abah, D., Teran, A.D, and Acheme, F.

Department of Agricultural Economics,
Federal University of Agriculture, Makurdi, PMB 2373, Makurdi, Nigeria.
Corresponding Authors' E-mail: daniel.abah@uam.edu.ng , dangod23@yahoo.com

ABSTRACT

This study assessed the effect of energy consumption on agricultural productivity in Nigeria. The study relied on the use of time series data spanning from 1981 to 2020. Data on the variables for the study were collected from the archives of Food and Agriculture Organization (FAO). Data for the study were analyzed using descriptive statistics, Johansen Co-integration test after testing for unit root and Vector Error Correction Model (VECM). The result of Augmented Dickey Fuller test for unit root indicated that all the variables were found to be integrated of order one and became stationary on first differencing. The Johansen co-integration test indicates that the computed trace statistics (75.94753) was greater than the critical value at 0.05 level (69.81889) at 0.05 level. Therefore, co-integration exists among the variables. The result of the VECM revealed that the coefficient of fuel wood, charcoal and electricity consumption were -20.041, 6.976 and -0.504, and statistically significant at 1%, 1% and 10% respectively; indicating the existence of long run effect of energy consumption on agricultural productivity. In the short run, change in the coefficient of fuel wood consumption (-0.498) and charcoal consumption (4.385) were statistically significant at 1% significant level. This implies that energy consumption has a significant effect on agricultural productivity in the short run. The study therefore recommends that, government should subsidize the prices of modern energy sources like electricity tariff which will help farming households in saving sufficient finance which will be invested in agricultural production.

Keywords: Energy, Consumption, VECM, Agriculture, Productivity

INTRODUCTION

Energy plays the most vital role in agricultural productivity, output and growth as well as economic growth and development of any nation (Danlami and Islam, 2019). Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. Conversely, a lack of access to energy contributes to poverty and can contribute to economic decline (Nnaji and Uzoma, 2010). Energy and poverty reduction are not only closely connected with each other, but also with the socio-economic development, which involves agricultural productivity, income growth, education, and health (Nnaji and Uzoma, 2010).

In 2020, Nigeria's GDP amounted to 152.32 trillion Naira; About 24% of GDP was generated by the agricultural sector. In the third quarter of 2019, the sector grew by 14.88% year-on-year in nominal terms with a decline of 3.44% points from the third quarter of 2018. The Agricultural sector contributed 29.25% to overall real GDP during the third quarter of 2019 (National Bureau of Statistics, 2021)

In addition to industrial energy consumption which accounts for a significant proportion of energy consumption, household energy consumption has attracted extensive interest (Stoppok, 2018). According to the data compiled by the International Energy Agency (IEA) in 2019, more than 20% of the total energy consumption of various Organization for Economic Co-operation and Development (OECD) countries was consumed by households. Also, the Department for Petroleum Resources (DPR) in 2020 reported an amount of petroleum of about 80% of the total energy consumption in Nigeria.

Energy is an important factor in all the sectors of any country's economy. The quest and utilization of energy have witnessed significant increase over the last two decades due to its pivotal role in real sector productivity which most importantly includes the agricultural sub-sector (Olayide, 2016). Agricultural productivity and development are easily attained especially among developing economies through intense utilization of energy such as electricity in value creation process (Osabuohien, *et al.*, 2019). In the present predicament as a nation, it is obvious that reducing the amount spends on petroleum and electricity consumption will provide more income for household investments in agricultural productivity.

Agricultural productivity is measured as the ratio of agricultural outputs to inputs. It is usually measured as the market value of the final output. This productivity can be compared to many different types of inputs such as labour or land. Such comparisons are called partial measures of productivity (United State Department of Agriculture, 2020).

Several studies have carried out studies on energy consumption in Nigeria. Danlami and Islam (2020) worked on explorative analysis of energy consumption in Bauchi State, Nigeria; Adamu *et al.*, (2020) focused on household energy consumption in Nigeria, a review on the applicability of the energy ladder model; Bamiro and

Ogunjobi (2021) worked on the determinants of household energy consumption in Nigeria: evidence from Ogun state among others. However, studies relating energy consumption and their corresponding impact on agricultural productivity in Nigeria are yet to be known. This study will therefore fill this research gap by analyzing the effects of energy consumption on agricultural productivity in Nigeria.

The study is of great importance because it is at a time when Nigeria is in dire need of increase in agricultural productivity in the current face of economic hardship. Findings from this study shall bring to the forefront policy formulation issues upon which recommendation shall be made. Furthermore, it shall bridge the literature gap that currently exist and be a source of knowledge to other researchers.

By providing information on estimates of long-run relationships that between energy consumption pattern and agricultural productivity, this study will broaden the knowledge on the nature of relationship among these variables as well as better understanding on the effectiveness of government policies in energy consumption and agricultural productivity in Nigeria.

The specific objectives of the study include to:

i. ascertain the existence of long-run relationship between energy consumption (electricity, fuel wood and charcoal) and agricultural productivity; and
ii. analyze the effect of energy consumption on agricultural productivity in Nigeria.

METHODOLOGY

The Study Area

The study area is Nigeria. Nigeria is located on the Gulf of the Guinea in West Africa with a geographical area of 923, 768 square kilometers. It is one of the eight most populous countries in the world with a population of about 140 million (NPC, 2006). With a population growth rate of 2.6%, Nigeria has an estimated population of about 210.87 million in 2021 (www.statista.com). Nigeria lies wholly within the tropics along the Gulf of Guinea on the western coast of Africa. The topography ranges from mangrove swampland along the coast to tropical rain forest and savannah to the north.

Nigeria is located between latitude 4°16 and 13°53 north and longitude 2°40 and 14°41 east (CIA Fact Book, 2009). Because Nigeria has a highly diversified agro-ecological climate, agriculture is one of the most important sectors of the Nigeria economy. The climate varies with Equatorial in South, Tropical in Centre and in the North. In the North, the vegetation is grassland savannah and in the south, forest. Because of this vegetation, agriculture is the major employer of labour in the country.

Data Collection and Data Analysis Techniques

The study made use of secondary data. Annual time series data spanning from 1981 to 2020 were sourced from Food and Agriculture Organization (FAO) database. Data for this study were analyzed using both descriptive and inferential statistics. Specifically, descriptive statistics, Johansen co-integration, Augmented Dickey Fuller (ADF) test and Vector Error Correction Model (VECM) were used for analysis in the study.

Vector Error Correction Model (VECM)

The vector error correction model was used to model causal influence between non stationary I (1) 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 VECM is estimated because a co integrating relationship deals only with long-run relationship without considering the short-run dynamics. The advantage of this procedure lies in the fact that both long run and short run influences of the endogenous variables in the model can be determined with the mechanism that keeps the variable in equilibrium evaluated.

$$\Delta \ln \mathrm{AGP_t} = \varphi_1 + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln FWD_{t-i} + \sum_{i=1}^{p} \beta_{1i} \Delta \ln CHC_{t-i} + \sum_{i=1}^{p} \gamma_{1i} \Delta \ln ELE_{t-i} + \sigma_1 ECT_{t-i} \dots\dots\dots\dots\dots\dots\dots.. (1)$$

where: $fands$ are mx1 vector of parameters; $\alpha, \beta, \emptyset$, μ and γ are mx1 and m x p vectors of parameters respectively; p is the optimal lag order that minimizes Information criteria; n is the number of endogenous variables under investigation (energy consumption and agricultural productivity); $?_{jt}$ is an mx1 vector of random variables assumed to be normally distributed white noise process.

Measurement of Variables

i. Fuel wood was measured in metric tonnes
ii. Charcoal was measured in tonnes
iii. Electricity was measured in watts or kilowatts (kw)
iv. Agricultural productivity was proxied by agriculture value added in percentages.

RESULTS AND DISCUSSION

Preliminary Analysis

Summary statistics of the Variables

The summary statistics of the variables used in the study is presented in table 1. The result showed that the variables electricity and agricultural productivity were positively skewed to the right tail implying the presence of more values that are higher than the sample mean while the variables fuel wood and charcoal were negatively skewed to the left tail implying the presence of more values that are lower than the sample mean.

The result further showed that the variables fuel wood, charcoal and electricity were platykurtic (negative kurtosis) with a kurtosis value of less than 3 implying that the distribution had a flatten curve relative to the normal. This shows that there were more values that are lower than the sample mean, however, the variable agricultural productivity was mesokurtic (positive kurtosis) with a kurtosis value greater than 3 which implies that there is a normal distribution of the variable.

More so, the result of the Jarque-Bera probability test of normality showed that all the variables (fuel wood, charcoal, electricity and agricultural productivity) were not statistically significant at 1% significant level having probability values greater than 0.05 (5%) which indicated the normal distribution of the variables used in the study.

Unit roots test

As shown in table 2, a necessary preliminary test, the Augmented Dickey Fuller (ADF) test for unit root was employed to test whether or not a variable is stationary and also determine the order of integration of the variable. The result indicated that all the variables (fuel wood, charcoal, electricity and agricultural productivity) were found to be integrated of order one and became stationary on first differencing. This indicates that the variables exhibit random walk (Unit roots) or the future values of these variables do not converge from their past values.

Table 1. Summary of Statistics of Variables

	Fuelwood	Charcoal	Electricity	AGP
Mean	57929815	3053874	107.1847	22.86948
Median	59523102	3100278	98.97802	22.0705
Maximum	66883138	4636741	156.7972	36.96508
Minimum	44266220	1469004	50.90104	12.24041
Std. Dev.	6623239	940005.6	28.76985	4.647603
Skewness	-0.474324	-0.076297	0.129925	0.442825
Kurtosis	1.9857	1.751784	1.727416	4.624443
Jargue-Bera	3.214565	2.635545	2.811652	5.705318
Probability	0.200432	0.267731	0.245164	0.057691
Sum	2.32E+09	1.22E+08	4287.39	914.7793
Sum Sq. Dev.	1.71E+15	3.45E+13	32280.48	842.4082
Observation	40	40	40	40

Source: Data Analysis, 2022

Table 2. Results of Augmented Dickey-Fuller (ADF) Test

Variable		**Level**							**First Difference**
	ADF	**1%**	**5%**	**10%**	**ADF**	**1%**	**5%**	**10%**	**Inference**
Fuelwood	-2.3731	-3.6156	-2.9411	-2.6091	-4.2871***	-3.6156	-2.9411	-2.6091	I(1)
Charcoal	-0.13179	-3.6105	-2.9390	-2.6080	-5.8305***	-3.6156	-2.9411	-2.6091	I(1)
Electricity	-1.79938	-3.6105	-2.9390	-2.6080	-8.2180***	-3.6156	-2.9411	-2.6091	I(1)
AGP	-2.5334	-3.6210	-2.9434	-2.6103	-6.8150***	-3.621	-2.9434	-2.6103	I(1)

AGP = Agricultural Productivity
*** Significant at 1%
Source: Data Analysis, 2022

Results of Co-Integration Test

According to Engle and Granger (1987) regressing a non-stationary series on another non-stationary series yields spurious regression, but if the linear combination of the series is stationary, we could say the variables are co-integrated and the regression is no longer spurious. Variables are said to be co-integrated if they have long run association. Since the variables are non-stationary, it becomes imperative to test whether or not the variables are co-integrated. Using both trace and maximum Eigen statistics, the result revealed that combination of these variables has one co-integrating equation and this means that linear combination of these variables has a single long run linear combination of relationship or one co-integrating equation.

The result (table 3) shows that the computed trace statistics (75.94753) is greater than the critical value at 0.05 level (69.81889). Similarly, the maximum Eigen value (39.25469) is also greater than the critical value (33.87687) at 0.05 level. Therefore, co-integration exists among the variables. This implies that a long run relationship exists among energy consumption variables and agricultural productivity.

Table 3. Johansen Co-Integration Test for Unrestricted Co-integration Rank Test

Trace **Hypothesised No. of CE(S)**	**Eigen value**	**Trace Statistics**	**0.05 Critical Value**	**Prob****
None*	0.644069	75.94753	69.81889	0.0149
At Most 1	0.431598	36.69284	47.85613	0.3622
At Most 2	0.206954	15.22562	29.79707	0.7653
At Most 3	0.149521	6.414427	15.49471	0.6465
At Most 4	0.006822	0.260116	3.841466	0.6100
Maximum Eigen value **Hypothesised No. of CE(S)**	**Eigen value**	**Max-Eigen Statistics**	**0.05 Critical Value**	**Prob****
None*	0.644069	39.25469	33.87687	0.0104
At Most 1	0.431598	21.46722	27.58434	0.2490
At Most 2	0.206954	8.811197	21.13162	0.8474
At Most 3	0.149521	6.154311	14.26460	0.5935
At Most 4	0.006822	0.260116	3.841466	0.6100

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values
Source: Data Analysis, 2022.

Vector Error Correction Model for Long and Short run Effects of Energy Consumption on Agricultural Productivity

Consequent upon the existence of one co-integrating equation among the variables, implying the existence of long run relationship among the variables, the Vector Error Correction Model (VECM) was estimated. The VECM shows the short run and long run effects of energy consumption on agricultural productivity in Nigeria. The result of the VECM as shown in table 4 indicated that in the long run, the coefficient of fuel wood consumption (-20.041) was negative and statistically significant at 1%. This implies that a unit increase in fuel wood consumption will decrease agricultural productivity by 20.041 units. Furthermore, the result showed that in the long run, the coefficient of charcoal consumption (6.976) was positive and statistically significant at 1%. This implies that a unit increase in charcoal consumption will increase agricultural productivity by 6.976 units *ceteris paribus*.

More so, the result showed that in the long run, the coefficient of electricity consumption (-0.504) was negative and statistically significant at 10%. This implies that a unit increase in electricity consumption will decrease agricultural productivity by 0.504 units.

The result indicated the existence of long run effect of energy consumption on agricultural productivity. This gives credence to the finding of Uchechukwu, Osabuohien and Hassan (2020) whose evidence from the lagged value of electricity consumed shows a significant impact on output from agriculture. The consumption of fuel wood and charcoal as a source of household energy leads to carbon dioxide (CO2) emissions, a main greenhouse gas, creating increasing concerns for climate change which affects agricultural productivity. This gives credence to the findings of Toole (2015) when he states that overdependence on fuel wood and charcoal exacerbates the process of deforestation and forest degradation through carbon dioxide (CO_2) emissions.

The result further shows that in the short run, change in the coefficient of fuel wood consumption (-0.498) was negative and statistically significant at 1% level of significance implying a unit increase in fuelwood consumption will lead to a 0.498 decrease in agricultural productivity in the second lag period. Also the coefficient of charcoal consumption (4.385) was positive and significant at 10% level of significant implying that a unit increase in charcoal consumption will increase agricultural productivity by 4.385 units in the first lag period. This implies that energy consumption has a significant effect on agricultural productivity in the short run.

The result of the short run indicated that Error Correction Term [ECT (-1)] is statistically significant and negative (-0.177) indicating a slow speed of adjustment. The result implies that 17.7% deviation from the equilibrium position is corrected within the year.
More so, the coefficient of multiple determination (R^2) is 67%. This implies that the independent variables were found to explain 67% of the variations in the dependent variable.

Table 4. The Vector Error Correction Model of Long and Short-run Effects of Energy Consumption on Agricultural Productivity in Nigeria

Long run	**Estimates**
Regressors	**CointEq1**
AGP (-1)	1.000000
Fuelwood (-1)	-20.041 (-4.078***)
Charcoal (-1)	6.976 (3.617***)
Electricity (-1)	-0.504 (-1.711*)
Constant	253.5123

Short run	**Estimates**			
ECM	**AGP**	**Fuelwood**	**Charcoal**	**Electricity**
CointEq1	-0.177 (-4.283***)	0.006 (0.480)	-0.003 (-0.182)	0.408 (1.697)
ΔAGP (-1)	-0.139 (0.838)	-0.018 (-1.150)	-0.015 (-0.668)	-0.045 (-0.249)
ΔAGP (-2)	-0.436 (-2.784**)	-0.001 (-0.040)	0.001 (0.056)	-0.018 (-0.107)
ΔFuelwood (-1)	-2.348 (-0.613)	0.258 (0.724)	0.195 (0.367)	4.119 (0.976)
ΔFuelwood (-2)	-0.498 (-3.128***)	-0.197 (-0.544)	-0.542 (-1.000)	6.261 (1.460)
ΔCharcoal (-1)	4.385 (1.981*)	0.110 (0.537)	0.277 (0.902)	-3.839 (-1.578)
ΔCharcoal (-2)	-0.342 (-0.133)	0.162 (0.676)	0.534 (1.493)	-3.137 (-1.107)
ΔElectricity (-1)	0.092 (0.613)	0.029 (2.072**)	0.045 (2.168**)	-0.354 (-2.147**)
ΔElectricity (-2)	0.005 (0.037)	0.001 (0.070)	-0.011 (-0.569)	-0.200 (-1.274)
Constant	-0.082 (-1.457)	0.0008 (0.145)	0.0079 (1.017)	0.118 (1.913)
R^2	0.67	0.317	0.566	0.516
Adj. R^2	0.515	0.090	0.548	0.322
F Statistics	3.839	1.394	2.732	2.140
Sum sq. resids	0.225	0.002	0.272	0.235
S.E. equation	0.091	0.008	0.013	0.100
Mean dependent	0.013	0.009	0.028	0.015
S.D. dependent	0.110	0.009	0.014	0.114

Likelihood 348.9161 Akaike Information Criteria -16.48195 Schwarz Criteria -14.56627

Figures in parentheses are t-values, *significant at 10%, **significant at 5%, ***significant at 1%

Source: Data Analysis, 2022

Stability Diagnostics Test

As shown in figure 1, a stability test was conducted to test the stability of the model. The model is statistically stable and can be used for policy direction because the gridline is perfectly between the 95% confidence interval.

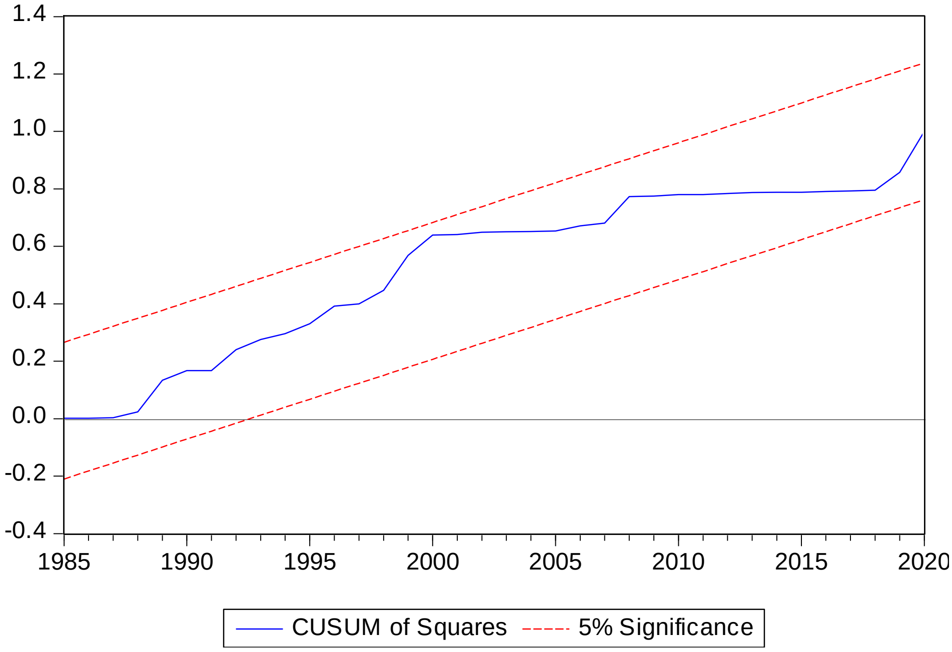

Figure 1. Stability Diagnostics test
Source: Data Analysis, 2022

CONCLUSION AND RECOMMENDATIONS

This research underscores the critical relationship between energy consumption and agricultural productivity in Nigeria. The Vector Error Correction Model (VECM) analysis revealed both short-term and long-term effects. In the long run, increased fuel wood consumption was found to significantly decrease agricultural productivity, while charcoal consumption had a positive impact. These findings align with previous research and highlight the environmental implications of energy choices, particularly in terms of carbon dioxide emissions. Moreover, in the short run, energy consumption was shown to have a significant influence on agricultural productivity, with a relatively slow speed of adjustment towards equilibrium. These results emphasize the need for sustainable energy practices to support and enhance agricultural productivity in Nigeria while addressing environmental concerns. The study therefore recommends that:

i. Government and policy makers encourage the adoption of cleaner and more sustainable energy sources for both household and agricultural use. This could involve government incentives and policies to transition away from highly polluting energy sources like fuel wood towards cleaner alternatives such as electricity or cleaner-burning fuels.

ii. Policy makers promote energy-efficient technologies and practices in agriculture to reduce the negative impact of energy consumption on productivity. This could include the use of energy-efficient equipment and practices in farming processes.

iii. Government should invest in rural electrification projects to provide reliable and clean electricity to rural farming communities. Access to electricity can improve agricultural productivity and reduce the reliance on carbon-intensive energy sources like fuel wood and charcoal.

iv. There should be increase awareness among farmers and the general population about the environmental consequences of energy consumption choices. Education campaigns can help people make informed decisions about their energy sources and their impact on agricultural productivity and climate change.

v. There is a need to develop long-term strategies for energy and agriculture that take into account the evolving needs of both sectors and the changing environmental landscape. This will ensure that policies and investments align with sustainable development goals.

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