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Impact of Internet Usage and Energy Consumption on Economic Growth in Nigeria: Evidence from Vector Error Correction Model

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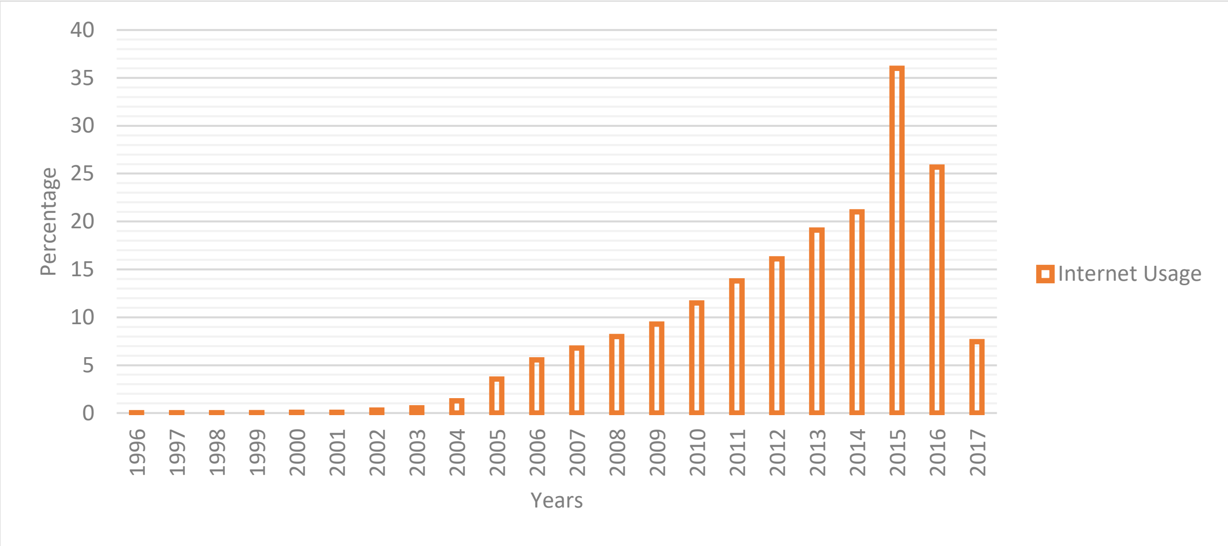
Abstract

This study estimated both long-run and short-run impact of internet usage and energy consumption on economic growth in the case of Nigerian economy between 1996-2014 and applied vector error correction model to analyzed the data on internet usage, energy consumption and economic growth. The breakpoint unit root test indicated that all the three series were concluded to be I(1) and cointegrated as shown by Johansen and Juselius test for cointegration. The long-run result from vector error correction model revealed that internet usage and energy consumption have significant positive impact on economic growth whereas CO_2 emissions exerts significant negative impact on economic growth. However, the result indicated that in the short-run energy consumption has a significant positive impact, while CO_2 emissions has significant negative impact on economic growth and slow adjustment speed estimated at 20.8 percent annually. The Granger causality result indicated that there is unidirectional causality flowing from internet usage to economic growth, CO_2 emissions to economic growth, CO_2 emissions to internet usage and economic growth to energy consumption. The empirical findings of this paper would serve as a beneficial tool for the same economies to offer proper ICT, energy consumption and economic growth-related policy decisions.

1.0 Introduction

There is significant progress in the increasing use of information and communication technology (ICT) over the past 3-decades as witnessed by the globe [1]. Although the fast-growing progress in the use of ICT is believed to bring about developments in the areas of production and efficiency of energy, its environmental influences are still unsettled. Snapshots of empirical studies that comprises of [2], [3] and [4] are of the view that ICT possess positive influence in mitigating the emissions of greenhouse gas, whereas other studies settled at ICT usage applies pressure on the use of energy via the resulting rise in the consumption of electricity which is one of the significant explanations for the universal emissions of CO_2 [5] and [6]. It is maintained that there is strong growth of about 11 percent for each year realized by the data centers concluded in the previous decade [7]. As indicated by the available information that about 1.1 to 1.5 percent of the total universal consumption of electricity is correlated with communication industry. Moreover, there was an increased in the consumption of electricity by the products and services of ICT from the initial 3.9 percent to about 4.6 percent worldwide in the year 2012 [8].

Figure 1 shows the trend of internet usage expressed in percentage of total population for the period of 1996 to 2017. Trend exhibited an increasing movement from 1996 when less than 1 percent of the total population are using the internet up to 2015 when 36 percent of the total population are using the internet. The trend declines from 2016 when 26 percent of the total population approximated to have access to internet to 2017 when only 7.5 percent of the total population approximately have access to internet respectively.



Source. Authors' presentation using World Bank Data, 2020
Figure 1: Trend of Internet Usage in Nigeria

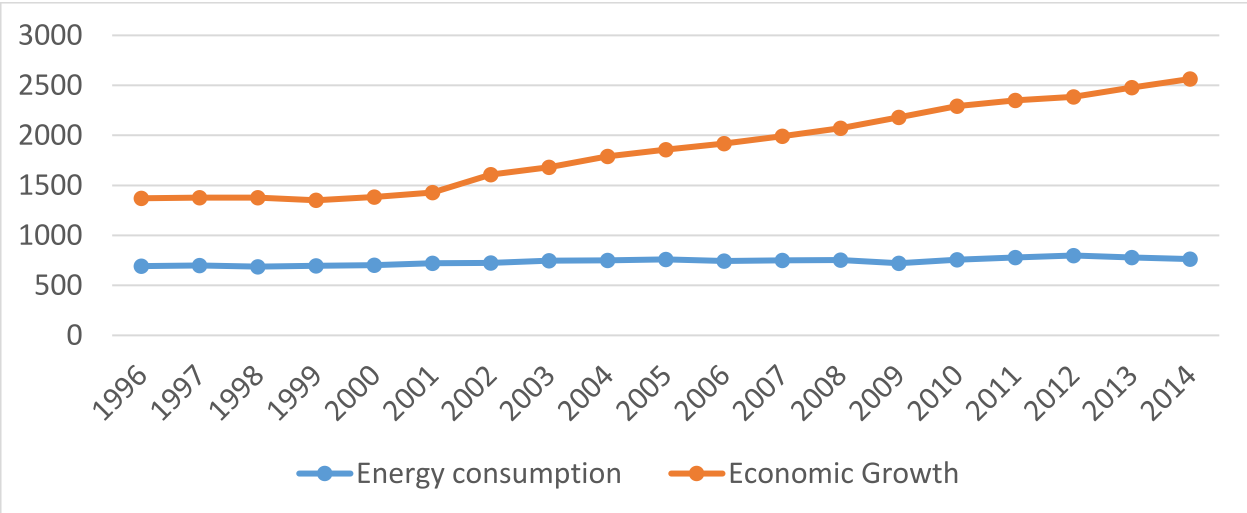
The significant role played by energy in human survival and in economic activities, both as economic scale, social development as well as basic humanitarian requirement cannot be overemphasized. Thus, a nation's energy consumption per capita is considered as a significant measure for achieving economic growth and eventual development. In our today's universe, energy is considered to be beyond input of production as it is seen as a strategic product that aid in establishing the foundation for global relations, profile of global economy and politics while the circumstances under which energy is obtained and the issues acknowledged in the obtaining process directly affect the struggle both at countrywide and global levels. These situations also outline the structures of a nations' production and establish one of the key measures of essential economic series. Given all these explanations, energy is considered as one of the greatest significant problems in our today's universal race [9].

In every advanced economy, the need for the secure access to modern energy that would support its growing prosperity and development is considered of paramount importance. Modern, higher quality and energy from reliable sources affords such services that ranges from lighting, transportation, mechanical power to communication that would also guarantee support to education, better and improve health care services, high level of income and outstanding progresses in terms of quality of life. Nations in sub-Saharan African are yet to overcome the task of energy poverty and barriers to doing so are conquerable while the benefits are achievable. In societies where there is energy poverty, the opening stage in evaluating the demand for future energy involved measuring the degree to which the population of the region lack access to modern energy and the problem is serious, as such electricity supply, use of solid biomass, deforestation and evaluation of strong social and economic effect can aid larger and improved access to modern energy delivery [10].

The significant role occupied by energy as input in production process was ignored by industrialized nations following the great oil crisis of 1970s. Subsequent to this period, energy, labour and capital were jointly regarded as production factors and from there a number of energies plus energy related studies started growing and these studies discourse only problems related to energy from different points of view. Some of these studies that are presented in economic literature considered energy as a problem of technical perspective, therefore, adopting that by existing technologies improvement or replacing with new technologies, it is likely to encounter greater demands for energy of nowadays when related with those of the past even though with the same volume of energy utilized by the economies in production or by humans in their everyday activities [11], [12] and [13].

After this great oil crisis of 1970s, the connection between economic growth and consumption of energy turned out to be a general investigating topic in both empirical and theoretical studies in addition to one of the key subjects of discussion in economic literature. For instance, some of the empirical examinations revealed that consumption of energy contributed to the nation's economic growth and among such empirical evidences include [14], [15], [16], [17], [18], [19] and [20] among others. The supporters of this positive relationship between consumption of energy and economic growth regarded it as "growth hypothesis" in economic literature alongside group of empirical evidence that oppose this argument and proposed that the role of energy is negligible or even neutral in economic growth and planned their assumption under the name "neutrality assumption" which according to this assumption any strategies aiming at reducing the consumption of energy has no effect on economic growth [21], [22], [23] and [24] among others.

Figure 2 indicated the graphical relationship between consumption of energy and economic growth for sample period spanning 1996-2014. The trends indicated an increasing movement from the first period of 1996 to the last period of 2014. But the increasing movement in the trend of economic growth is greater than that of the energy consumption.



Source. Authors' presentation using World Bank Data, 2020.
Figure 2: Trends of Economic Growth and Energy Consumption in Nigeria.

1.1 Related Literature Review

The review of literature in this study is divided into two categories. The first category is concerned with the connection between internet usage and economic growth while the second category is centered on the economic growth and energy consumption relationship.

1.1.1. Internet Usage and Economic Growth Nexus

[25] in their investigation for the effect of ICT investment on the consumption of energy, the outcome of their investigation indicated that in the service and manufacturing sectors, investment in ICT increased the level of electricity consumption and the total results is in line with the fact that rise in the use of ICT led to rise in energy efficiency. [26] reported that the use of ICT has caused an increased in the consumption of electricity in the case of emerging nations when he investigated the connection between the use of ICT and electricity consumption in the case of the emerging economies by applying dynamic panel approach. [27] examined the effect of ICT on carbon dioxide emissions using time series data and the result of the investigation revealed that ICT has the potential to decline carbon dioxide emissions for over 50 years' time and they recommended the incorporation of pricing of universal carbon into the policy of ICT.

In the case of 77 developed and developing nations for the period spanning 2000 to 2013, [28] studied the effect of internet retailing on the level of carbon dioxide emissions and their result of the study from the panel method revealed that economic growth, electricity consumption, trade openness and urbanization are the key drivers of carbon dioxide emissions in general from the case studies. Again, internet retailing has negative and significant influence on carbon dioxide emissions in the case of developed nations but internet retailing has not significantly signed on carbon dioxide emissions in the developing nations. In a similarly investigation carried out by [29] on the effect of ICT industry on carbon dioxide emissions for the sample period of 2000 to 2010 in the case of the Chinese economy, the empirical result indicated that via efficiency energy gains, the ICT use has decreased the level of carbon dioxide emissions within the study period. [30] maintained that there exist a significant ICT enabled carbon dioxide emissions reduction possibilities in the transportation sector of the economy whereas with general GPS usage, smart phones together with other connected devices all in the public transportation sector can possibly contribute towards saving energy. In a study done by [31] on the impact of ICT on economic growth and energy consumption in the case of Japanese economy reported that there may be possible decrease in the energy consumption through gains in energy efficiency from the use of ICT.

1.1.2. Energy Consumption and Economic Growth Nexus

The second section of the literature review focused on the connection between economic growth and consumption of energy in different parts of the world. Studies have revealed that there are conflicting findings regarding the relationship between energy consumption and economic growth [32].

For instance, the pioneer work of [33] who documented a report regarding the connection between economic growth and energy consumption in the case of the United States from 1947 to 1974 and immediately after their famous work, numerous empirical studies started flowing with different approaches of investigation. [34] studied the connection between economic growth, CO_2 emissions and energy consumption from 1960 to 2005 using 19-European member countries and applied ARDL and Granger causality techniques. Their result indicated long-run relationship between the series and one-way causality flowing among the series in the 7 member nations. In their investigation for the long-run causal connections between energy consumption (renewable and non-renewable) with economic growth for the study period spanning 1980-2009, [35] applied ARDL model and causality test in order to determine the long-run and causal relationships among the interest series. The result revealed that both renewable and non-renewable energy consumption have no effect on economic growth. But the causality result indicated that the causal relationships depend on whether the production function is augmented or it is based on the classical production function.

In investigating the effect of crude oil price volatility on economic growth of Nigeria for the period of 1970 to 2010, [36] utilized VAR approach in achieving the aim of the investigation. The empirical result indicated that volatility in crude oil price effects the real exchange rate, imports and government expenditure but real money supply, inflation and real economic growth were indirectly affected by the volatility in crude oil price via government expenditure. In the case of Brics nations, [37] examined the correlation among economic growth, consumption of renewable energy, emissions of carbon dioxide and trade openness for the sample period of 1970-2010. In analyzing the data for empirical result, ARDL and VECM techniques were applied. The outcome of the investigation indicated an existence of long-run connection among the series and the VECM outcome indicated that there is a two-way causality running from consumption of renewable energy to economic growth. By considering the case of 7-Central American nations for the period spanning 1980-2010, [38] studied the association existing between renewable energy consumption, emissions of carbon dioxide and fossil fuel prices. Their outcome revealed that there is an existence of the long-run connection among these series and that all the series exhibit positive and significant relationship with each other.

In modeling the connection existing between the electricity generation from various forms of renewable sources in the case of 20-OECD nations for the sample period of 1990-2008, [39] revealed that there is an evidence of cointegration relationship among the series as indicated by the panel Pedroni test for cointegration and also there is an existence of two-way hypothesis between hydroelectricity and economic growth in the short-run period. In his investigation for the effect of crude oil price fluctuation on the Nigerian economic growth for the 1970-2014 periods, [40] applied the framework of aggregate demand together with Engel-Granger cointegration test in analyzing the data on the interest series for the purpose of realizing the sole objective. The outcome revealed that crude oil fluctuation exerts an unfavorable effect on the Nigerian economy even though crude oil revenue and reserves have significant positive effects on the Nigerian economy. In the case of net crude oil exporting nations and by considering the sample period of 1980 to 2012 and applied panel cointegration test for the existence of long-run relationship among the interest variables, [41] examined the connection existing between energy consumption from renewable source and their empirical outcome indicated that there is an existence of cointegration relationship among the interest variables.

By considering the case of Egyptian economy for the sample period of 1989 to 2013, [42] studied the relationship between electricity generation from renewable source and unemployment rate with the aid of ARDL approach in analyzing the data. The outcome revealed that there is an existence of inverse connection between electricity generation from renewable source and unemployment rate in the short-run period. [43] in their investigation for the connection between economic growth and consumption of energy in two consecutive forms that include consumption of energy from non-renewable source and consumption of energy from renewable source applied ARDL approach and their empirical outcome revealed that there is no existence of cointegration among economic growth and energy consumption from renewable source but there is cointegration among economic growth and energy consumption from nonrenewable source. The outcome further showed that two-way causality exists which flows from non-renewable energy consumption source to economic growth in the two periods alongside one-way causality from non-renewable energy consumption to economic growth in the long-run. In the case of Azerbaijan for the sample period of 1990-2015, [44] explored the causal connection among consumption of energy and economic growth and applied causality test using Toda and Yamamoto technique within the VAR framework in the exploration process. The outcome showed that there is an existence of two-way causality from energy consumption and economic growth in the long-run.

In the case of South African economy, [45] studied the connection between the energy consumption from renewable source and economic growth for the sample period of 1990 to 2014. After reporting the existence of cointegration relationship among the series, the authors want ahead to show that there is an existence of one-way causality flowing from the renewable energy consumption to economic growth and from economic growth to renewable energy consumption in the long-run and short-run respectively. [46] result through VECM approach showed that price of crude oil and real effective exchange rate exerts positive influence on economic growth of the case study while inflation and government expenditure had significant negative effect on economic growth. Again, causality runs from crude oil price to economic growth and exchange rate whereas inflation was granger caused by exchange rate. The VDC outcome showed that fluctuation in crude oil price is the source of deviation in exchange rate and economic growth while major source of variation in inflation is exchange rate and crude oil price in their study for the effect of fluctuation in crude oil price on economic growth from 1981 to 2015. [47] showed that economic growth and energy consumption are the key drivers of carbon dioxide emissions for the period of 1971 to 2013 after recognizing the long-run relationship between the interest variables using bounds test result in the ARDL framework. Result from Granger causality test revealed that there exist unidirectional causality running from economic growth to carbon dioxide emissions in the case of Chinese economy.

In modeling the effect of renewable energy consumption on unemployment in the case of South African economy, [48] considered the time series data for the period of 1991 to 2014 and applied ARDL approach to analyze the data. The outcome revealed that renewable energy consumption exerted significant negative influence on unemployment rate in the long-and-short runs, the outcome showed an insignificant relationship among the variables. In their investigation for the existing relationship between economic growth, energy consumption, foreign direct investment and environmental pollution in the case of 6 sub-Saharan African nations for the 1980-2014 period and utilized panel ARDL in achieving the key objective, [49] reported that there is two-way causality between energy use and carbon dioxide emissions in the short-run with one-way causality between energy use and CO_2 emissions while from CO_2 emissions to foreign direct investment in the long-run. To [50] economic growth and energy consumption had exerted significant positive influence while crude oil price has significant negative influence on environmental pollution in the two periods when they applied ARDL approach to investigates the impact of economic growth and energy consumption in the case of Nigerian economy for the sample period of 1981 to 2014. In another development, [51] examined the association between renewable energy consumption and unemployment in the case of Nigerian economy for the period of 1991 to 2015 through the application of T-Y causality procedure and the result showed that bidirectional causality flows from consumption of renewable energy to unemployment, foreign direct investment to consumption of renewable energy, investments to consumption of renewable energy, private sector credit to investments alongside one-way causalities from investments to unemployment and private sector credit to unemployment.

From literature and to the best of our knowledge studies related to the current study are scarce in the case of Nigerian economy. Thus, this paper stands to investigate the impact of internet usage and energy consumption on economic growth of Nigeria using vector error correction model and Granger causality test.

2.0 Methodology

This paper explored the connection existing among energy consumption, internet usage and economic growth in the case of Nigerian economy between the period of 1996-2014. The choice of this study period was highly influenced by the availability of data on the explain and the explanatory variables. Data on all the interest variables were extracted from the database of World Development

Indicators (WDI) of World Bank and the variables included are economic growth (measured as GDP per capita, constant 2010 US$); Energy consumption (measured as energy use, kg of oil equivalent per capita); Internet usage (measured as individuals using the internet, % of population); CO_2 emissions (measured as metric tons per capita). But before conducting the empirical investigation, we have taken the natural logarithm of all the variables in order to reduce the possible occurrence of serial correlation and heteroscedasticity problems [52] and [53] and to achieved linearity assumption. In order to derive the empirical model connecting the dependent and independent series, we have employed the production function equation given as:

$$Q = f(L, K) \quad (1)$$

Where Q represent the total outputs and is replace by economic growth (EG_t); Labour is given by L and is replaced with internet usage (IU_t); capital is represented by K and it will be replaced by energy consumption (EC_t) and the level of CO_2 emissions is introduce in the model as a control variable. The modified empirical model is given in Equation 2.

$$EG_t = f(IU_t, EC_t, CO_{2t}) \quad (2)$$

The functional form given in Equation 2 is transformed into econometric model by adding stochastic error term to capture the effects of other factors that influence economic growth apart from internet usage and energy consumption that were not included in the model as offered in Equation 3.

$$\ln EG_t = \theta_0 + \theta_1 \ln IU_t + \theta_2 \ln EC_t + \theta_3 \ln CO_{2t} + \mu_t \quad (3)$$

Where sign of natural logarithmic is denoted by ln; θ_0 denote the drift parameter; $\theta_1 \ldots \theta_3$ represents the explanatory variables coefficients to be estimated; economic growth is represented by EG_t; IU_t represent internet usage; EC_t represent energy consumption; CO_{2t} represent carbon dioxide emission and white noise is given by μ_t.

After estimating the ordinary least squares in Equation 3, we continue to determine the levels of integration of our series and determine the number of times a variable must be differentiated to achieved the level of stationarity via unit root test. In this search, we have utilized the breakpoint unit root test because of its power to overcome the problem of structural breaks in the series. A major requirement to cointegration is that the variables need to be at the same levels of integration. This requirement is confirmed with the aid of breakpoint unit root test and the test is done using level forms and first difference forms with constant and with constant and trends on each while the suitable number of lags is selected based on Schwarz information criterion (SIC).

After knowing the unit root result or the level of integration of our variables, we employed the [54] test for cointegration and the VECM model. The Johansen test for cointegration is the approach of maximum livelihood for cointegration determination in a vector autoregressive (VAR) model with single reason of discovery a linear mixture which is most stationary through depending on the association among the matrix rank and its eigenvalues counterpart.

Opening with the VAR framework and for easy explanation, we let X_t to be a vector of I(1) series offered in the Equation 4:

$$X_t = A_t X_{t-1} + A_t X_{t-2} + \ldots \ldots A_n X_{t-n} + \mu_t \quad (4)$$

Here $n \times 1$ is given by the $\sum_{i=1}^{k} A - I$ and μ_t respectively.

Remodeling Equation 4 gives Equation 5:

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i X_{t-i} + \prod X_{t-i} + \mu_0 + \varepsilon_t \quad (5)$$

Where $\prod = \sum_{i=1}^{k} A - I$ and $\Gamma_i = -\sum_{j=i+1}^{k} A_j$

There is $n \times 1$ matrices and α and β each with a c rank such that $\prod = \alpha\beta'$ and $\beta' X_t$ matrices are stationary. This possible only if the reduced c < n rank where the number of cointegration equation is given by c, adjusted parameters are given by α and each of β in the VECM framework and the cointegrating vectors.

Based on the suggestion given by the [55] regarding the trace and maximum eigenvalues in examining the statistical significance and the reduced matrix rank of $\prod$, these tests are given in Equations 6 and 7:

$$J_{trace} = -M \sum_{j=c+1}^{n} \ln(1-\hat{\delta}_i) \tag{6}$$

$$J_{\max} = -M \ln(1-\hat{\delta}_{c+i}) \tag{7}$$

Here the number of observations is given by M and $\hat{\delta}_i$ represent the largest number of observations given as ith.

As claim by Johansen and Julieus the trace statistic test the H_0 of c cointegrating connection as against the H_a of n cointegrating vectors and n represent the amount of series in the model. Equally, the eigenvalue maximum tests the H_0 of c cointegrating vectors against the H_a of c+1 cointegrating vectors. The critical values which are offered by the Johansen and Julieus and [56] are conveyed by the econometric software such as Eviews 10 which is used in all the estimation process in this paper. After examining the cointegration connection among the series, the paper continues to estimate the subsequent vector error correction model (VECM) which consists of both long-run dynamics alongside the short-run error correction (ECM) model and the VECM is specified from Equations 8 to 12.

$$\Delta \ln EG_t = \theta_0 + \sum_{j=1}^{k} \phi_1 \ln EG_{t-j} + \sum_{j=0}^{k} \chi_1 \ln IU_{t-j} + \sum_{j=0}^{k} \vartheta_1 \ln EC_{t-j} + \sum_{j=0}^{k} \delta_1 \ln CO_{2t-j} + \varpi ECT_{t-1} + \varepsilon_{1t} \tag{8}$$

$$\Delta \ln EG_t = \phi_0 + \sum_{j=1}^{k} \phi_1 \Delta \ln EG_{t-j} + \sum_{j=0}^{k} \phi_2 \Delta \ln IU_{t-j} + \sum_{j=0}^{k} \phi_3 \Delta \ln EC_{t-j} + \sum_{j=0}^{k} \phi_4 \Delta \ln CO_{2t-j} + \partial ECT_{t-1} + \varepsilon_{2t} \tag{9}$$

$$\Delta \ln IU_t = \vartheta_0 + \sum_{j=0}^{k} \vartheta_1 \Delta \ln EG_{t-j} + \sum_{j=1}^{k} \vartheta_2 \Delta \ln IU_{t-j} + \sum_{j=0}^{k} \vartheta_2 \Delta \ln EC_{t-j} + \sum_{j=0}^{k} \vartheta_3 \Delta \ln CO_{2t-j} + \pi ECT_{t-1} + \varepsilon_{3t} \tag{10}$$

$$\Delta \ln EC_t = \delta_0 + \sum_{j=0}^{k} \delta_1 \Delta \ln EG_{t-j} + \sum_{j=0}^{k} \delta_2 \Delta \ln IU_{t-j} + \sum_{j=1}^{k} \delta_3 \Delta \ln EC_{t-j} + \sum_{j=0}^{k} \delta_4 \Delta \ln CO_{2t-j} + \psi ECT_{t-1} + \varepsilon_{4t} \tag{11}$$

$$\Delta \ln CO_{2t} = \theta_0 + \sum_{j=0}^{k} \delta_1 \Delta \ln EG_{t-j} + \sum_{j=0}^{k} \delta_2 \Delta \ln IU_{t-j} + \sum_{j=0}^{k} \delta_3 \Delta \ln EC_{t-j} + \sum_{j=1}^{k} \delta_4 \Delta \ln CO_{2t-j} + \upsilon ECT_{t-1} + \varepsilon_{5t} \quad (12)$$

Where the coefficient of error correction term which is gotten from the cointegrating vector and measures the response influence or the adjustment speed toward long-run equilibrium following a shock from economic growth, internet usage, energy consumption and CO_2 emissions in equations 9, 10, 11 and 12 as represented by $\varpi, \partial, \pi, \psi$ and υ, white noise is represented by $\varepsilon_{1t} \ldots \varepsilon_{5t}$ as all other variables maintain their normal descriptions given in the previous equations.

The technique of Granger causality was propounded by [57] and for instance, if the dependent variable says EG_t granger caused one independent variable say energy consumption given as EC_t then it implies that EG_t can be projected with greater certainty through the past values of EC_t as all other things been equal. In that case, we estimate the granger causality using the VAR model as given in the system equations from 13 to 16:

$$\ln EG_t = \beta_0 + \sum_{j=1}^{k} \beta_1 \ln EC_{t-j} + \sum_{j=0}^{k} \beta_2 \ln IU_{t-j} + \sum_{j=0}^{k} \beta_3 \ln CO_{2t-j} + \sum_{j=0}^{k} \beta_4 \ln EG_{t-j} + \varepsilon_{1t} \quad (13)$$

$$\ln EC_t = \varphi_0 + \sum_{j=1}^{k} \varphi_1 \ln EG_{t-j} + \sum_{j=0}^{k} \varphi_2 \ln IU_{t-j} + \sum_{j=0}^{k} \varphi_3 \ln CO_{2t-j} + \sum_{j=0}^{k} \varphi_4 \ln EC_{t-j} + \varepsilon_{2t} \quad (14)$$

$$\ln IU_t = \gamma_0 + \sum_{j=1}^{k} \gamma_1 \ln EG_{t-j} + \sum_{j=0}^{k} \gamma_2 \ln EC_{t-j} + \sum_{j=0}^{k} \gamma_3 \ln CO_{2t-j} + \sum_{j=0}^{k} \gamma_4 \ln IU_{t-j} + \varepsilon_{3t} \quad (15)$$

$$\ln CO_{2t} = \alpha_0 + \sum_{j=1}^{k} \alpha_1 \ln EG_{t-j} + \sum_{j=0}^{k} \alpha_2 \ln EC_{t-j} + \sum_{j=0}^{k} \alpha_3 \ln IU_t + \sum_{j=0}^{k} \alpha_4 \ln CO_{2t-j} + \varepsilon_{4t} \quad (16)$$

From the Equations 13, 14, 15 and 16 above we test for $H_0 : \sum_{j=1}^{k} \beta_i = 0$; $H_0 : \sum_{j=1}^{k} \varphi_i = 0$; $H_0 : \sum_{j=1}^{k} \gamma_i = 0$ and $H_0 : \sum_{j=1}^{k} \alpha_i = 0$ respectively. We reject each H_0 if the computed F-statistic is greater than the critical value at a reasonable significance level otherwise we do not reject H_0. Rejecting the H_0 in Equation 13 implies that internet usage and energy consumption Granger caused economic growth and that past values of the formers significantly predict economic growth. Similarly, rejecting H_0 in Equation 13 also implies that economic growth Granger causes internet usage and energy consumption as such the past values of economic growth could be used to predict internet usage and energy consumption in question and the same applies to all the remaining equations.

3.0 Results and Discussion

The analysis of the variables kicked off with the trend graphical illustrations of economic growth, internet usage, energy consumption and the level of CO_2 emissions for the sample period of 1990 to 2014 in the case of the Nigerian economy. The trends of economic growth and that of internet usage exhibited an upward movement while the trends of CO_2 emissions and energy consumption shows fluctuating movement at an increasing rate. These graphical illustrations given in Figure 3 for all the four variables indicated how connected these series are to each other within the sample study period.

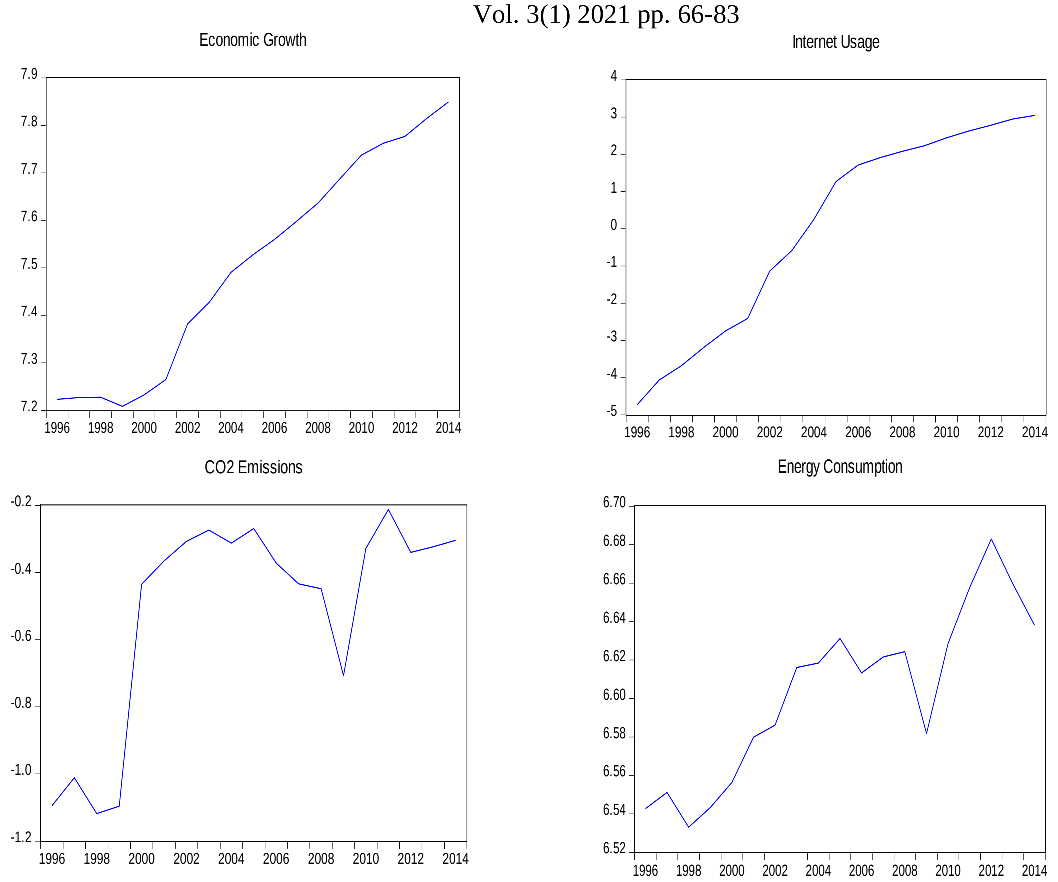


Figure 3: Trends of economic growth, internet usage, CO_2 emissions and energy consumption in Nigeria

As shown in Table 1, the average value of economic growth is 1866.320; internet usage is 6.161 percent; energy consumption is 738.331 kg of oil equivalent; 0.624 is for CO_2 emissions. The maximum values in the series include 2563.900 for economic growth; 21.000 for internet usage; 798.630 for energy consumption and 0.808 for CO_2 emissions while the corresponding minimum values are economic growth 1350.984; internet usage 0.008; energy consumption 687.507 and CO_2 emissions 0.326. The standard deviation values show the amount of variability in the series. The p-values of all the Jarque-Bera coefficients are insignificant thereby confirming the existence of normality among the interest series. Hence, economic growth and internet usage have positive skewness coefficients while energy consumption and CO_2 emissions have negative skewness. Moreover, economic growth and internet usage are positively skewed while energy consumption and CO_2 emissions are negatively skewed. The correlation coefficients reported in the lower part of the Table 1 indicated that all the values are within the bench mark of 0.80 which signifies that there is absence of multicollinearity problem among our series [58].

Table 1: Descriptive Statistics and Correlation Analysis

Series	Mean	Minimum	Maximum	SD	JB	Skewness
EG_t	1866.320	1350.984	2563.900	423.306	1.587 [0.452]	0.169
IU_t	6.161	0.008	21.000	7.102	2.482 [0.288]	0.822
EC_t	738.331	687.507	798.630	32.398	0.784 [0.675]	-0.025
CO_{2t}	0.624	0.326	0.808	0.164	3.349 [0.187]	-0.977
	EG_t	IU_t	EC_t	CO_{2t}		
EG_t	1.					
IU_t	0.344	1.				
EC_t	-0.491	-0.143	1.			
CO_{2t}	0.236	0.243	0.699	1.		

Note. Values in square brackets [ ] are the p-values.

After the descriptive and correlation analysis outcomes reported earlier, the empirical analysis continued with test for the unit root using the breakpoint unit root test and the result is reported in Table 2. The motive for applying the breakpoint unit root test rather than the traditional Augmented Dickey Fuller (ADF) and the Philip Perron (PP) tests for unit root is that the breakpoint unit root test has the power to tackle the problem of structural breaks in the series which the two traditional unit root tests of ADF and PP does not have. The outcome from the test in Table 2 indicated that virtually all the variables were stationary at first difference using both constant and trend. Therefore, all the variables are said to be integrated of order one or more commonly known as I(1). Given that all the series are I(1) gave the perfect room for the application of Johansen test for cointegration and the VECM for the long-run, short-run and the error correction relationship among the variables.

Table 2. Breakpoint unit root test result

Description	Variables	t-Statistic	Lag-Length	Break-Date
Levels				
Intercept	$lnEG_t$	-1.493	2	2007
	$lnIU_t$	-2.019	0	1999
	$lnEC_t$	-3.343	3	2011
	$lnCO_{2t}$	-6.201***	0	1999
Intercept and trend	$lnEG_t$	-4.511**	2	2011
	$lnIU_t$	-3.804	3	2008
	$lnEC_t$	-3.002	0	2005
	$lnCO_{2t}$	-3.511	0	2003
First differences				
Intercept	$lnEG_t$	-5.430***	2	2005
	$lnIU_t$	-4.692**	0	2005
	$lnEC_t$	-5.796***	2	2009
	$lnCO_{2t}$	-6.094***	0	2000
Intercept and trend	$lnEG_t$	-4.608**	3	2002
	$lnIU_t$	-4.543**	0	2004
	$lnEC_t$	-4.775**	0	2013
	$lnCO_{2t}$	-4.714**	0	2000

All variables in natural logs, lag lengths are determined via SIC and the null of all test is unit root.
*** Indicates significance at 1%.
** Indicates significance at 5%.
* Indicates significance at 10%

Given that all the variables are stationary at first difference, the determination of the optimum lags that would give the best outcome for the cointegration relationship among the variables set in and the estimation of the main model. The optimum lag result offered in Table 3 revealed that lag 3 is the best lag for the model estimation as suggested by the five information criteria of LR, FPE, AIC, SC and HQ respectively. But given that the optimum lag is determine by the information criterion does not mean that the selected lag is free from the problem of serial correlation and others and for that reason, we have carried out some diagnostic tests on the selected lag and the outcome is presented in the lower part of the Table 3. The diagnostic test outcomes revealed that the selected lag is free from the problem of serial correlation, heteroscedasticity, normal distributed as indicated by their p-values greater than 0.05 and it is stable as indicated by the inverse roots of AR characteristic polynomial in Figure 4. Therefore, the maximum lag for this research paper is 3.

Table 3: Optimum Lag Selection Result

Lag	LogL	LR	FPE	AIC	SC	HQ
0	39.208	NA	0.000	-4.142	-3.946	-4.122
1	107.529	96.453	0.000	-10.297	-9.317	-10.200
2	136.674	27.430*	0.000*	-11.844*	-10.079*	-11.668*
VAR Diagnostic checks						
Serial Correlation Test:	8.204 [0.942]					
Normality Test:	8.529 [0.577]					
Heteroscedasticity Test:	159.864 [0.275]					
Stability Test:	Stable					

Note. Values in [] are the p-values.

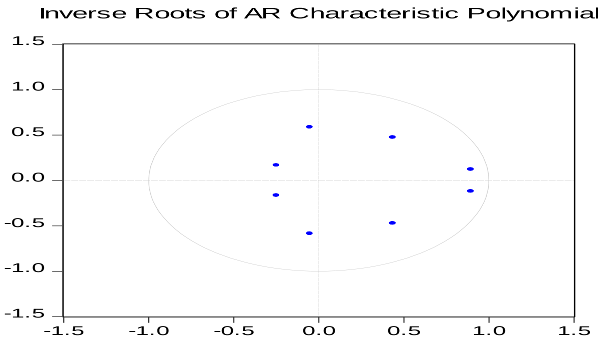


Figure 4: VAR Stability test.

After knowing that the best lags for the analysis to be 3 and the optimum lag is free from all the problems using some diagnostic checks, then the determination of the long-run equilibrium relationship became imperative and the result of the cointegration relationship using Johansen and Juselius test for cointegration is given in Table 4. The outcome indicated that there is an existence of strong single cointegration equation in the trace statistics and max-eigen value models and it is therefore concluded that there is long-equilibrium association among our variables and they said to move together in the long run.

Table 4: Johansen-Juselius Cointegration Test Result

H_o	Eigenvalue	J_{trace}	J_{max}	5%-Critical values
C = 0	0.971	83.862*** [0.000]	60.606*** [0.000]	27.584
C ≤ 1	0.555	23.255 [0.233]	13.794 [0.328]	21.131
C ≤ 2	0.357	9.461 [0.324]	7.521 [0.429]	14.264
C ≤ 3	0.107	1.940 [0.163]	1.940 [0.163]	3.841

Note. Values in [] are the p-values.

The existence of cointegration relationship among our interest variables as given in the Table 4 necessitated the estimation of the long-run and short-run relationships among the variables and the estimation was done using VECM and the outcome is reported in Equation 11 and Table 5. In Equation 11, internet usage has significant positive impact on economic growth as shown by the positive sign and the t-statistic value presented in []. Precisely, one percent increase in internet usage caused 0.063 percent increase in economic growth in the long-run period. This is in consistent with work of [59] for OECD countries. Similarly, energy consumption exerted significant positive impact on the economic growth of Nigeria in the long-run as shown by the positive sign and the t-statistic value presented in []. Specifically, one percent increase in energy consumption in the country is associated with 6.445 percent increase in economic growth in the long-run within the study period. This finding corroborates the empirical findings of [60], [61] for Turkey. But contracts the outcome of [62] for Cote d'Ivoire who reported insignificant relationship between energy consumption and economic growth. However, carbon emissions possessed negative and significant relationship with economic growth as indicated by the negative sign and the t-statistic value. This implies that percentage increase in carbon emissions is associated with 0.920 percent decrease in economic growth in the long-run and this possible because the country is not well industrialized. This finding contracts the findings of [63] and in the case of 12 MENA nations who reported positive and significant relationship between CO_2 emissions and economic growth.

$$\ln EG_t = 35.530 + 0.063\ln IU_t + 6.445\ln EC_t - 0.920\ln CO_{2t} + \varepsilon_t \quad (11)$$
$$[-12.522] \quad [-18.767] \quad [24.692]$$

After the long-run relationship result given in Equation 11 which indicated that the existing relationship between economic growth with internet usage and economic growth with energy consumption is positive while that of economic growth and carbon dioxide emissions is negative.

Here comes to the short-run and error correction results as offered in Table 5. The outcomes indicated that energy consumption has significant positive impact on economic growth in the short-run. Specifically, a percentage change in energy consumption is associated with 0.533 percent increase in economic growth. While CO_2 emissions has significant negative impact on the economic growth in the short-run. Hence, a percentage change in the CO_2 emissions is associated with 0.119 percent decrease in economic growth. Therefore, the short-run result in terms of energy consumption and CO_2 emissions is in line with that of the long-run. The speed of adjustment is indicated by the value of the error correction term. The value of the error correction term (ECT) is 0.208 which means that adjustment speed from the short-run dynamic disequilibrium position back to the equilibrium position is at 20.8 percent every year within the study period. The R-square value of 0.567 implies that 56.7 percent variations in economic growth is explained by internet usage, energy consumption and CO_2 emissions while the remaining 43.3 percent is captured by error term.

The adjusted R-square value of 0.370 indicated that due to adjustment in the model, 37 percent variations in economic growth is responsible by internet usage, energy consumption and CO_2 emissions respectively while 63 percent variation is accounted by other factors that are not captured in our model. The Durbin Watson value of 2.04 indicated that there is absence of first order serial correlation problem in our estimated model because the DW value fall within the range of 1.5-2.5. The VECM result was subjected to some diagnostic checks of serial correlation, heteroscedasticity and normality problems and the results were reported in the lower part of Table 5. The diagnostic test results indicated that all the tests coefficients' p-values were insignificant which necessitated acceptance of null hypothesis for all the tests and concluded that the result of the VECM is free from above mentioned problems and therefore reliable for policy making.

Table 5. VECM Short Run Result

Series	Coefficient	Std. Error	t-Statistic	P-values
Constant	0.057^{***}	0.014	4.078	0.000
ΔEG_{t-1}	-0.234	0.325	-0.720	0.475
ΔIU_{t-1}	-0.024	0.019	-1.251	0.217
ΔEC_{t-1}	0.533^{*}	0.305	1.743	0.088
ΔCO_{2t-1}	-0.119^{**}	0.046	-2.586	0.013
ECT_{t-1}	0.208^{***}	0.071	2.899	0.005
		Diagnostic Tests		
R^2	0.567	A. Serial Correlation:	15.310	0.502
Adj- R^2	0.370	B. Normality Test:	4.627	0.796
D/W-Stat.	2.044	C. Heteroscedasticity:	91.504	0.716

Note. A. VECM Serial Correlation Test
B. VECM Jarque Bera Test
C. VECM Heteroscedasticity Test
***, ** & * represent 1, 5 and 10% levels of significance.

Since the variables are cointegrated, here comes to the causal relationship among economic growth, energy consumption and CO_2 emissions using Granger causality test and the result of the test is offered in Table 6. The result indicated that there are unidirectional causalities flowing from internet usage to economic growth, CO_2 emissions to economic growth, CO_2 emissions to internet usage and economic growth to energy consumption. The causality between economic growth and energy consumption is in conformity with the empirical findings of [64] in the case of Ghanaian economy, in the case of Algerian economy by [65], [66] for Armenia, and [67] in the case of Turkey. The rest of the result can be obtained in Table 6.

Table 6. Granger Causality Outcome

From	To	F-Statistic	P-values
Internet usage	Economic growth	2.894*	0.094
Energy consumption	Economic growth	0.614	0.557
CO_2 emissions	Economic growth	3.270*	0.073
Energy consumption	Internet usage	0.601	0.563
CO_2 emissions	Internet usage	9.421***	0.003
CO_2 emissions	Energy consumption	0.969	0.407
Economic growth	Internet usage	0.975	0.404
Economic growth	Energy consumption	4.130**	0.043
Economic growth	CO_2 emissions	0.107	0.899
Internet usage	Energy consumption	2.571	0.117
Internet usage	CO_2 emissions	0.116	0.891
Energy consumption	CO_2 emissions	0.055	0.946

The test statistics follow a X^2 distribution with 2 lags.
Indicates significance at 10%.
Indicates significance at 5%.
Indicates significance at 1%.

4.0 Conclusion

A lot of studies have explored the influence of information and communication technology on economic growth and energy consumption on economic growth in different parts of the world. But, exploring the influence of internet usage and energy consumption on economic growth in the case of the Nigerian economy is still scarce. This current study examined the influence of internet usage and energy consumption on economic growth in the case of the Nigerian economy for the period of 1996 to 2014 using VECM approach.

The long-run equilibrium relationship among economic growth, energy consumption and carbon dioxide emissions were confirmed using the Johansen and Juselius test for cointegration. The VECM long-run result indicated that internet usage and energy consumption exerted significant positive impact on economic growth which means that access to internet and energy consumption in the country contributed to the growth of the Nigerian economy while CO_2 emissions is having significant negative impact on economic growth.

In the short-run, the VECM result indicated that energy consumption is still having significant positive impact on economic growth while CO_2 emissions is having significant negative impact on economic growth. The speed of adjustment from the short-run dynamic disequilibrium back to the equilibrium position is low estimated at 20.8 percent every year within the sample period of 1990-2014.

Economic growth is granger caused by internet usage and CO_2 emissions which implies that there is unidirectional causality flowing from internet usage to economic growth and from CO_2 emissions to economic growth. Internet usage is granger caused by CO_2 emissions while energy consumption is granger caused by economic growth. This implies that there is unidirectional causality running from CO_2 emissions to internet usage and economic growth to energy consumption respectively.

Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work.

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