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AN EMPIRICAL EVIDENCE OF ENERGY CONSUMPTION AND ECONOMIC DEVELOPMENT DYNAMICS IN NIGERIA: WHAT IS THE ROLE OF POPULATION?

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ABSTRACT

The place of population growth in the linkage between the consumption of energy and economic development in Nigeria was examined in this study. Annual data on total consumption of energy, the growth of population, and economic development were employed among other variables for the time 1995 to 2019. We used Autoregressive Distributed Lag -Error Correction Model (ARDL-ECM). Energy consumption had a feedback negative substantial relationship with economic development in the long run while in the short run, energy consumption had a negative significant impact on economic development. The population growth had a negative significant impact on economic development, and a positive substantial effect on energy consumption. However, energy consumption is not impacted on by oil price. Consequently, we advocate for the increase in the quality of energy, increasing government expenditure in the provision of energy supply, and the population maximization of energy for the achievement of economic development in Nigeria.

Contribution/ Originality: The novelty and contributions of this study are that it took into consideration some relevant variables, population growth, and the price of oil (oil is a major source of energy in Nigeria) which had little recognition in previous studies on the analysis of energy consumption and economic development.

1. INTRODUCTION

Energy is often considered a necessary commodity and a significant factor in the economic growth and development of nations (Ito, 2017). There is a current increase in the global use of energy rising to a 4.6% increase in 2021 (IEA, 2022). A major reason for this can be the increase in the amount of energy for global activities towards achieving development (industrialization, urbanization, investments, boosting productivity, and the quest for a more comfortable living among others). Also, the rising global population, particularly from the developing countries. However, there is a current call for a reduction in energy consumption as the first consequence of the need to mitigate the amount of pollution, and global warming towards sustainable development. Hence, there seems to be a trade-off facing the global economy, necessitating the examination of the nexus between the consumption of energy, population, and economic development.

Sub-Saharan Africa has been recorded to be the lowest in development as compared to other continents and also the highest in population. For every two persons added to the world population, one is expected to be from Africa. The continent is projected to be the world's most populous by 2023 (Africa Development Bank, 2019). This has resulted in a growing demand for energy which is higher than that of China and second India's demand. SSA has the lowest amount of energy consumption, particularly modern energy. An estimate of 83% of families is still using traditional energy (Africa Energy Outlook, 2019). According to IEA (2022), all countries of SSA except South Arica are found at the bottom of the Energy Development Index (EDI) ranking. Africa Energy Outlook (2019), also noted that for countries with increasing economic growth, SSA is the only region project to experience a fall in per energy consumption from 2015 to 2040 as a result of the rapid population growth rate. Hence, the demand for SSA meeting with its growing need for energy is crucial.

Nigeria happens to be the most populated country in Sub-Saharan Africa and the 7th highest populated country in the world. The country has a population of 206 million in 2020 with a growth rate of 2.65% which is projected to rise to 350million in 2050 (Worldometer, 2022). Nigeria is also among the low developed countries. Data showed that Nigeria's GDP per capita for 2019 was $2,230, which was a 9.97% increase from 2018, while the RGDP per capita growth rate fell continuously from 9.89 in 1990 to -5.95 in 2020 (Macrotrend, 2022). The country's HDI was 0.45 in 2019, failing to rank to 161 from a rank of 158 in 2018 out of 189 countries that were ranked (United Nation Development Report, 2020).

Absolute poverty also a manifestation of the level of development was estimated to be about 70% (133.62million) on the US$ 1 per day poverty line, and multidimensional poverty of 51.4% (98.12million) in 2017 (UNDP, 2019). In terms of energy, the country is blessed with a lot of various resources putting the country as the 10th highest oil-producing country. Nevertheless, there is a contradiction in conjunction of lots of instinctive resources and a dearth of modern natural resources with extreme poverty. Total energy consumed in Nigeria was 1.54 quadrillion BTU in 2017 which is about 0.26% of global energy consumption. In 2020, energy consumption per capita was 0.8toe while electricity consumption per capita was 140 kWh/hab, the third-lowest in SSA. Also, only 18% were found to have access to clean flue and technology for cooking in 2020 (Enerdata, 2021; World Bank, 2022). Given the above scenario, it has become paramount to investigate the nexus between the consumption of energy, and economic development in the face of sustainable development in Nigeria.

It is still contentious whether the high population is the foremost contributor to the high per capita energy consumption whether the height of the consumption of energy per capita is a contributing variable to the level of development or whether the level of energy consumption is a consequence of the level of development. Thus, the amount of the consumption of energy can be a cause as well as an outcome of some economic development level. As acknowledged by Huang and He (2018) an increase in population size corresponded to double the increase in energy consumption.

The complexity of the linkage between the population, economic growth, and energy consumption has recently attracted some concern with conflicting results. Some studies found a positive effect of economic growth on energy consumption, and a long-run relationship between them (Nyiwul, 2017; Rahman, 2020; Shahbaz & Lean, 2012; Tariq, Huaping, Haris, & Yusheng, 2018). Some other studies (Ghali & El-Sakka, 2004; Nyiwul, 2017) found energy not to have a significant impact (minimal role) on the growth of the economy, since economic growth results in a shift to the service sector, which requires less energy need. Others (Vo, 2021) also found a feedback causality between economic growth and energy, while others found that energy responds positively to population growth and density (Rahman, 2020; Vo, 2021). However, there still remains a gap in the literature on whether population plays an intermediate role between the consumption of energy and economic development connectivity. Neither has the connectivity between economic development and energy consumption been given consideration in developing countries (SSA), particularly in Nigeria. A close study to this was on the role of economic complexity on economic growth and energy nexus. Economic complexity was found to have a strong significant impact on economic growth (Gozgor, Lau, & Lu, 2018).

Given the global drive toward clean energy, and the challenges of the use of traditional energy which are often cheaper and easily available for the developing countries and the growing population, it has thus become imperative to ask; how significant dose population affects energy consumption in Nigeria given the treats of increasing energy demand on sustainable development? How significant is the nexus between energy consumption and economic development? Can there be a feedback relationship between energy consumption and economic development? Hence, the objective of this study is to determine if there exists a feedback significant connectivity between the consumption of energy and economic development in Nigeria given the population. The identified gap in the literature is therefore filled by this study and it has added to the existing studies in the following ways: First, it explored the role of the population in the consumption of energy and economic development connection. Secondly, the study examined the existence of feedback connectivity between energy consumption and economic development to determine where policy emphasis will be laid. Thirdly, the study used the most recent and robust data of the Human Development Index (HDI) as a proxy variable for economic development.

2. REVIEW OF RELATED LITERATURE

2.1. Theoretical Literature

2.1.1. Energy Consumption

Energy consumption is the sum of energy or power used for different purposes by different individuals, households, countries, or the entire world (Ogbeide-Osaretin, 2021). Based on the sources, energy can be fossil fuel, firewood, coal, crop and animal residuals, biomass electricity, solar, and many others. The amount of energy that is consumed can be determined by some variables such as the population or household size, the level of education, and the development of the country.

2.1.2. Economic Development

Economic development is the transformation of a nation from a low-income to a modern industrialized nation as well as its political and social status. It is also the increase in per capita income and the reduction in income inequalities of the people. Kindleberger and Herrick (1958) cited in Todaro and Smith (2011) defined economic development to mean the improvement in the welfare of the people, eradication of poverty, improvement of the quality of health, structural change from agriculture to industrial activity, political and social changes and the participation of the majority in decision making. It can be concluded that economic development has to do with the reduction of poverty, unemployment, and inequality while there is an increase in capita income.

2.1.3. Population Growth

This is an increase or fall in the number of people in an area for a period of time. It is mainly affected by the number of births, death, emigration, and immigration. When the birth rate and immigration are more than the emigration and death rate, we have a positive population growth (Hinde, 1998). This growth can be in absolute or relative terms. Relative is concerned with percentage change while absolute is the number.

2.1.4. Energy Consumption, Population, and Economic Development Theories Population and Economic Development Linkage

Population growth and human capital have been the central force behind the theories of economic development (Klasen & Santos-Silva, 2018). The theory of Malthus- Ehrlich- Brown noted that when the population is growing more than output, it will lead to a miserable state if the population is not checked. Kuznets- Simon-Boserup's theory on the contrary noted that population is a necessity for growth. This is because the size of the population is not only labour but includes technical progress. Aligning with the "genius principle" and the "population pressure" the higher the population, the more the stock of ideas. Hence, it is expected that the growth of the population will stimulate the innovation of technology given the scarce resources (Birchenall, 2016).

Population growth has been identified as a stimulant to economic growth and development, through an increase in the labour force, productivity, and the market size for the sale of the output. The increase will stimulate entrepreneurs to invest more in capital goods and machinery. Economic activity will be spurred, income increased, poverty reduced and economic development achieved. However, the growth and developmental impact of the population depends on the ability of the economic system to absorb and productively employ these added workers. Also, the population density to the natural resources and total output tends to retard growth and development through a lower per capita income. Hence, the positive relationship between population growth and economic development can only be sustained by the control of the population growth rate.

2.2. Energy Consumption and Economic Development Linkage

The linkage between energy consumption and economic development can be likened to the consumption theory. The theory of energy transition is the theoretical foundational linkage between the consumption of energy and economic development. This theory believes energy consumption is directly connected to income level (Njiru & Letema, 2018). The theory further explains that the income level of an individual, household, or nation determines the type of energy that is consumed (Hosier & Dowd, 1987; Leach, 1992). Various views and theories have however been put forward in analyzing the nexus between energy and economic growth. The various views and outcomes of these studies have resulted in four hypotheses and schools of thought regarding energy consumption and economic growth (implying development) nexus.

The neutrality hypothesis: according to this hypothesis, there is no relationship between energy consumption and economic growth/development. The study of To, Wijeweera, and Charles (2013) provides credence to this hypothesis.

The growth hypothesis: this noted that economic growth is a function of energy consumption. Thus, a unidirectional causality is believed to run between then with energy causing economic growth/development running from energy to growth. Thus, the low or unavailability of modern energy supply impedes economic development as energy is a necessity to power economic development (Ekeocha, Penzin, & Ogbuabor, 2020).

The conservation hypothesis: conservation hypothesis is based on the notion that economic growth and development are not a function of energy consumption. Rather, energy consumption increases with an increase in economic growth and development. It thus implies that policy on the conservation of energy can be effectively carried out (Ouedraogo, 2013). This hypothesis was supported by the studies of Keppler (2007), for India.

The feedback hypothesis: finally, this fourth hypothesis shows that feedback connectivity exists between the consumption of energy and the growth/development of the economy. Thus, there is a strong complementarity between them.

2.3. Energy Consumption, Population, and Economic Development Linkage

Energy is vital for all economic activities and hence central to sustainable development. The sources, users, and the purpose for which energy is being used seem to be connected and have drawn attention to energy. In the extreme, energy use rather than the output of goods is used as an indicator of the state of economic development (e.g. Kardashev, 1964 cited in Antia, Udo, and Ikpe (2015)). The availability of efficient energy services is widely accepted as an essential driver of economic growth and development; access to enhanced health, education, and better economic opportunities are dependent on an efficient energy supply. Population growth has been seen to be correlated (positive/negative) to economic growth and development.

Hence, an increase in population implies an increase in energy use. Also, an increase in the desire for more growth by the economies of the world leads to an increase in the use of energy. Hence, there is a positive linkage between population and energy use. There also seems to be generally a positive relationship between economic development and energy use. From the above, the linkage between energy consumption, population, and economic development can be represented in Figure 1.

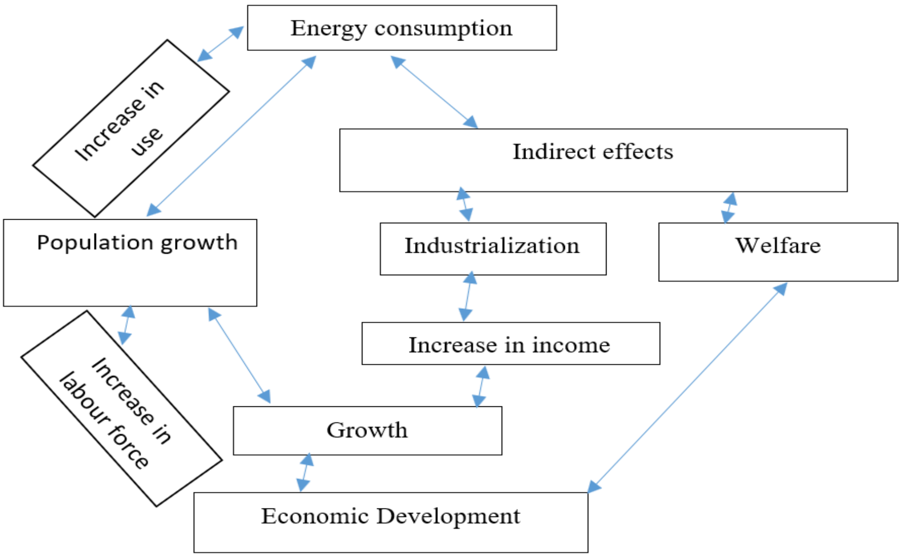

Figure 1. Nexus among energy consumption, population and economic development.

2.4. Empirical Literature

The study on the synergy between energy and performance of the individual economies has received quiet attention. This increased when energy that was supposed to be a means of economic growth for the comfort of humanity, seems to be a problem to humanity.

2.5. Energy, Economic Growth, and Economic Development

Analyzing the relationship between energy consumption and economic growth, Shahbaz and Lean (2012) discovered a long-run, while, a nonlinear relationship was found in a study carried out by Heidari, Katircioğlu, and Saeidpour (2015) on five ASEAN countries. Sebri and Ben-Salha (2014) employing an ARDL bounds testing method of estimation and the vector error correction model (VECM) technique for the period 1970 to 2010, investigated the relationship between economic growth, trade openness, renewable energy consumption, emission of carbon dioxide on for the Brics countries. The outcome revealed that a long-run relationship exists among the variables. A bi-directional causality was also found to flow between renewable energy consumption and economic growth.

Okoligwe and Ihugba (2014) made use of the error correction model (ECM) and Granger causality test to investigate the energy consumption and economic growth relationship in Nigeria from 1971 to 2012. A one-way causality was found to flow from energy consumption to economic growth. But, in the study carried out by Mustapha and Fagge (2015), on the synergy between the consumption of energy and Nigeria's economic growth, the study made use of annual data from 1980 to 2011 which was estimated by the VEC and granger causality test. The outcome showed no causality between the variables rather, variance decomposition revealed that capital and labour a more important factors for the growth of output and not energy consumption. Antia et al. (2015) employed a VAR method of estimation to analyze the direction of the functional synergy between energy consumption, economic growth, and sustainable economic development in Nigeria. It was revealed from the result that there exists a bidirectional synergy between economic growth and energy consumption which significantly impacts economic development. Nyiwul (2017) on the other hand examined the feedback association between the consumption of energy and economic growth in Sub- Saharan Africa (SSA). The result showed a positive influence of economic growth on renewable energy while renewable energy consumption was found to have a non-significance influence on economic growth. Hence, a one-way relationship between the two variables flowing from energy consumption to economic growth. Investigating the link between economic growth and energy consumption in developing countries, Tariq et al. (2018) made use of four developing countries (Pakistan, India, Bangladesh, and Sri Lanka). The instrumental variable estimation method was used for the period 1981 to 2015 and urban population, FDI, and trade were included as control variables. Economic growth was found to lead to an increase in energy consumption while trade was negatively related to energy consumption given its introduction of energy-efficient technology.

The work of Gozgor et al. (2018), made use of a 29 OECD countries panel data set for the period 1990-2013 and a modified growth model in investing the nexus between energy consumption and economic growth. The ARDL and panel quantile regression (PQR) estimation methods were used. The study showed that all form of energy (renewable and non-renewable) and economic diversity strongly and positively affects economic growth. Following this, Khan, Khan, and Rehan (2020) decided to investigate the environmental impact of energy consumption. They investigated the nexus between economic growth, energy consumption, and emission of Co_2 in Pakistan over the time 1965 to 2015. The ARDL method of estimation was employed and the result showed that CO2 is increased from the consumption of energy and the quest for economic growth both in the short-run and long run.

2.6. Energy Consumption, Population, and Economic Growth and Development

On the nexus among energy consumption, population growth, economic growth, and sustainable development, Rahman (2020) examined the effect of international trade, economic growth, and population density on energy consumption and the quality of the environment in India. The annual data of 1971 to 2011 in an ARDL bound testing method of estimation and the Granger causality was used. The result revealed feedback positively and significant impact on energy consumption on the one hand, and population density and economic growth on the other hand. Odugbesan and Rjoub (2020) examined the synergy between the consumption of energy, the growth of the economy, carbon dioxide (CO2) emissions, and urbanization using four countries (Mexico, Indonesia, Nigeria, and Turkey) countries). Annual data from 1993 to 2017 were used on an ARDL bond test estimation approach. A unidirectional causality was revealed to flow from the consumption of energy to growth for Nigeria and Indonesia while a bidirectional relationship was found for Mexico and Turkey. However, economic growth, energy consumption, and CO2 emissions were found to have a long-run relationship with urbanization in the four countries.

Nwani and Osuji (2020) explored the dynamics among the population, energy consumption, and the misery index to determine how population, misery index, economic development, and energy consumption impact poverty in sub-Saharan African countries. A panel data covering the period 1990 to 2018 was used and estimated with the panel least square. The outcome revealed that the misery index magnifies poverty. Population growth, access to improved sanitation, economic development, and per capita energy consumption significantly impact poverty reduction in the region. There was also causation between poverty and the explanatory variables except for inflation. Amoah, Kwablah, Korle, and Offei (2020) investigated the relevance of economic welfare and freedom to achieve renewable consumption of energy. The study made use of the ratio of renewables in the total amount of energy consumption on a panel of 32 African countries over the period 1996-2017. The Dynamic Ordinary Least Squares estimation method was used to account for the identification problem. The outcome showed that the enhancement in economic welfare enhances the portion of renewables in the total consumption of energy leading to an inverted U shape. Property rights, as well as tax burden, lead to a fall in the ratio of renewables in total energy consumption. An increase in trade freedom on the other hand increases the share of renewables in total energy consumption.

Following the above studies, Vo (2021) also carried out a study using time series data to examine the connectivity among population growth, energy consumption, economic growth, and sustainable development.

The advanced panel vector autoregressive model and the Granger non-causality test for heterogeneous panels were used on a sample of seven countries from the Association of Southeast Asian Nations (ASEAN) for three decades from 1990. The study revealed that the use of renewable energy increases with an increase in population growth which leads to an increase in the emission of carbon dioxide (CO2). Also, a bidirectional causality was found to exist among the various pairs.

2.7. The Gap in Literature and Contribution to Knowledge

The effect of energy consumption on economic growth has been studied reasonably in literature (list). While most of these studies focused on the causal relationship between the two (list), required attention has not been given to a major determinant of energy which is population. This especially is for developing countries where there is rapid population growth. Also, the price of energy which is a function of the supply and demand of energy has not been considered for developing countries and Nigeria in particular. While it is well recognized that economic growth is good for the country and many studies have also found that energy is vital for the achievement of growth, the role of energy in the achievement of development has not been given attention in developing countries, and Nigeria in particular. This is vital given the global goal of sustainable development and the energy was noted to be addressed (goals 7, 11, and 13). Furthermore, following, the basic theory of consumption, energy consumption can also be a function of the level of development measured by the RGDP per capita or human development index. Hence, this study contributes to knowledge and fills these gaps in Nigeria's study given the high population of Nigeria, her low level of development, and the paradox of having abundant sources of energy yet facing energy poverty.

3. METHOD OF THE STUDY

3.1. Theoretical Framework

Energy has been revealed to play a vital role in the growth process. This was based on the theory of Solow (1956) growth which argued that natural resources (capital, labour, and land) are important factors of production and economic growth. However, the Classical and neoclassical economists did not recognize energy as a factor of production and hence important for economic growth. Following some other studies (Okwanya & Abah, 2018), this study, rests on a foundation of Solow growth, the Malthus- Ehrlich- Brown theory, and the feedback hypothesis. The Solow growth theory recognizes natural resources including energy as vital for economic growth and development.

The Malthus- Ehrlich- Brown theory noted that given the population growing at a very fast rate more than natural resources and output, will lead to insufficiency of these natural resources (energy) and a miserable state if not checked. The feedback hypothesis posits that energy consumption is vital for economic development. Also, in line with the energy transition theory that poor access to energy reduces the developmental potential of a country. The feedback hypotheses however further noted that as the consumption of energy (especially modern energy) increases the level of development, is determined by the amount of energy that can be consumed by the country.

3.2. Model Specification

The primary driving force of the growth in an economy is the growth of productivity according to the exogenous growth models. However, the endogenous growth theory emerged to correct some of the weaknesses of the exogenous growth model and noted that human capital investment, innovation, and knowledge are vital contributors to economic growth.

Following the AK production model, the simplest production function is given as:

$$Y = AK \quad (1)$$

With:

A, being a positive constant showing the economy's level of technology.

K is capital.

In line with Romar's model, a common production function is stated as;

$$Y = f(AK, L) \quad (2)$$

With:

A being innovations (changes in technology).

K being the capital stock.

L being the stock of labour.

'A' among others is the development of new ideas.

Thus, deriving the production function from the endogenous theory, we have:

$$Y=F\ (A, K, L) \tag{3}$$

Where

Y is aggregate real output.

K is stock of capital.

L is stock of labour (population).

A is technology (changes in technological inputs).

Following the work of Gbadebo and Okonkwo (2009), A is a function of investment in research technology which is seen as an endogenous factor and can be related to energy since all economic processes need energy. Given that output growth (economic growth) will translate to economic development, the above growth model is modified to model the impact of energy consumption and population on economic development in Nigeria.

Following other studies, Khan et al. (2020); Ekeocha et al. (2020); Odugbesan and Rjoub (2020) and on our presumed linear relationship among the variables, this study employed the linear Autoregressive Distributed lad model (ARDL). According to Pesaran and Pesaran (1997) cited in Ekeocha et al. (2020) and Odugbesan and Rjoub (2020), ARDL gives a more efficient and unbiased result in the face of small size sample. Furthermore, when there are conflicting unit root results, the ARDL is a better test for co-integration. Ekeocha et al. (2020) also noted that some of the challenges associated with static models; serial correlation of the error tem, and the independent variables suffering from endogeneity, are corrected when ARDL is used especially in finite samples (Ekeocha et al., 2020). Thus, the linear form of the basic ARDL model is given as:

$$Y_t = \alpha_0 + \alpha_1 \sum_{i=1}^{p} \Delta Y_{t-1} + \alpha_2 \sum_{i=1}^{q} \Delta X_{i-j} + \mu_{t.} \tag{4}$$

Where:

X_t = All other explanatory variables.

$i, j, j-k, j-1$ = Unknown lags orders of the ARDL model, to be selected using Akaike Information Criteria (AIC).

εt is the i.i.d. error term.

In line with the feedback theory of the energy consumption and economic development linkage, this study used a multi-equation model.

$$DEVP_t = \alpha_0 + \alpha_1 \sum_{i=1}^{n} \Delta\, DEVP_{t-1} + \sum_{i=1}^{n} \Delta X_{i-j} + \mu_{2t} \tag{5}$$

$$ENC_t = \alpha_0 + \alpha_1 \sum_{i=1}^{n} \Delta ENC_{t-1} + \alpha_2 \sum_{i=1}^{p} \Delta\, DEVP_{i-j} + \alpha_3 \sum_{i=1}^{n} \Delta X_{i-j} + \mu_{1t} \tag{6}$$

Where ENC is the total energy consumption and DEVP is the level of development.

Following Olayeni (2012) ENC which is the total energy consumption is measured as commercial energy use in kilograms of oil equivalent per capita. DEVP is measured by human development index.

Equation 5 and 6 recognizes that the response of economic development to energy consumption on the one hand and the response of energy to economic development is not instantaneous but dynamic. Government expenditure is included as control variable in both equation following the study of Akinlo (2008) while in line with Wolde-Rufael (2009), capital and price of energy (as input of energy production and determinant of energy consumption) are included in the energy equation.

Thus Equation 5 and 6 in the reduced form and including in the long run all the variable is given as:

$$DEVP = \alpha_0 + \alpha_1 DEVP_{t-1} + \alpha_2\, ENC_{t-1} + \alpha_3\, POPg_{t-1} + \alpha_4 K_{t-1} + \alpha_5\, HHS_{t-1} + \alpha_6\, EXPEN_{t-1} + \varepsilon t1 \tag{7}$$

$$ENC = \beta_0 + \beta_1 ENC_{t-1} + \beta_2 DEVP_{t-1} + \beta_3\, POPg_{t-1} + \beta_4\, K_{t-1} + \beta_5\, OP_{t-1} + \beta_6\, EXPEN_{t-1} + \varepsilon t2 \quad (8)$$

Where

DEVP= Economic development captured by Human development index.

ENC = Energy consumption captured by energy use in kilograms of oil equivalent per capita.

POPg = Population growth.

K= stock of capital which is captured by GFCF = Gross fixed capital formation.

OP= Average price of energy.

HHS= Average household size. It is a control for economic development. It is expected that the higher the HHS the lower the level of development. Empirically justified by Ichoku, Agu, and Ataguba (2012); Ogbeide-Osaretin. (2021).

FDI=foreign direct investment. It is expected that higher level of FDI, the higher the amount of energy that is consumed from more industrial, technological and economic activities.

EXPEN=Government total expenditure (N, Billion). This also includes expenditure on energy provision.

In the estimation of (3.7) and (3.8), we proceed first to test for the stationarity of the variables. Given the outcome of the unit root test, the ARDL bounds testing procedure of was used to check for the co-integration of the variables. With the establishment of the co-integration among the variables, short-run dynamics of the models was estimated, given as:

Also the short run was estimated in the ARDL-ECM,

$$\Delta DEVP = \alpha_0 + \sum_{i=1}^{n} \alpha_2\, \Delta\, DEVP_{t-1} + \sum_{i=1}^{n} \alpha_2\, \Delta\, ENC_{t-1} + \sum_{i=1}^{n} \alpha_3\, \Delta\, POPg_{t-1} + \sum_{i=1}^{n}{}_{\alpha_4}\, \Delta\, K_{t-1} + \sum_{i=1}^{n}{}_{\alpha_5}\, \Delta\, HHS_{t-1} + \sum_{i=1}^{n} \alpha_6\, \Delta\, EXPEN_{t-1} + \partial ECM1 + \varepsilon t1 \quad (9)$$

$$\Delta ENC = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta\, ENC_{t-1} + \sum_{i=1}^{n} \beta_2 \Delta\, DEV_{t-1} + \sum_{i=1}^{n} \beta_3 \Delta\, POP_{t-1} \sum_{i=1}^{n} \beta_4 \Delta\, K_{t-1} + \sum_{i=1}^{n} \beta_5 \Delta\, OP_{t-1} + \sum_{i=1}^{n} \beta_6 \Delta\, EXPEN_{t-1} + \partial ECM2 + \varepsilon t2 \quad (10)$$

Where the ECM1 and ECM2 are the error term of the development and energy consumption equations respectively.

3.3. Data

The Annual data spanning from 1995 to 2019 was employed for this study. The data was sourced from World Bank (2020) and Statista (2022). Data on average household size was sourced from National Bureau of Statistics, while, government total expenditure was obtained from the Central Bank of Nigeria, Central Bank of Nigeria Statistical Bulletin (2021). The analysis is estimated using the E-views 9 econometric package.

4. EMPIRICAL STRATEGY

4.1. Correlation Test

Table 1 shows the correction test which was employed to determine the intensity of multi-collinearity among the variables. The result as presented in the correlation matrix, revealed that there is no perfect multicollinearity among the variables given their correlation coefficients of not more than 0.85 which was between energy consumption (ENC) and economic development (HDI) and this is however not server. As observed by Gujarati and Porter (2009), when r is greater eight (>8), we should suspect multicollinearity in the model. The estimate is inflated when we have a perfect multicollinearity where R^2_k is greater than 0.9, or r between the variables is greater nine (>9) (Gujarati & Porter, 2009).

Table 1. Correlation matrix

Variable	HDI	ENC	POPG	GFCF	HHS	OP	EXPEN
HDI	1						
ENC	0.85	1					
POPG	0.72	0.80	1				
GFCF	0.75	0.56	0.42	1			
HHS	0.68	0.83	0.72	0.37	1		
OP	0.63	0.77	0.91	0.38	0.78	1	
EXPEN	0.93	0.81	0.61	0.77	0.62	0.60	1

4.2. Stationarity Test

In testing stationarity of the dataset, we employed the Augmented Dickey-Fuller test. The result revealed that all variables are integrated of order one, I(1) with the exception of population growth (POPg) which was found stationary at levels (see Table 2).

Table 2. Unit root condensed result using ADF.

Variable	Levels	5% Critical	1st Diff.	5%Critical	Remark
HDI	-1.47	-2.99	-6.85	-3.00	I (1)
ENC	-1.63	-2.99	-5.02	-3.00	I (1)
POPG	-3.63	-3.01			I (0)
GFCF	-0.04	-3.00	-7.98	-3.01	I (1)
HHS	-2.04	-2.99	-5.10	-3.01	I (1)
OP	-1.55	-2.99	-4.27	-3.00	I (1)
EXPEN	-1.40	-3.03	-303	-3.02	I (1)

4.3. Model Estimation

4.3.1. Estimation of the Development Equation

4.3.1.1. Result from Long-Run ARDL Establishment

Analyzing the diagnostic test first to determine if the model is good and result robust for interpretation, the result of the coefficient of determination R^2, auto correction result (DW and Breusch–Godfrey serial correlation test) and the Heteroskedasticity test (Breusch-Pagan-Godfrey result) and the Ramsey test all came out in excellent order. Hence, allowing us to use the result for policy recommendation.

Table 3. ARDL long run estimation of economic development.

Dep. Var= L(Economic Development) (LHDI)			
Method = ARDL; Selected Model = ARDL(1, 1, 1, 0, 1, 1) **Diagnostics : R^2** = 0.88; **F-Stat.** = 103 **F-Pro**.= 0.00; **DW** = 1.77; Pro (BG test): = 0.65; Pro (BPG test)= 0.62; Pro (Ramsey test)= 0.09			
Independent Variable	**Coefficient**	**t-sat**	**Probability**
L(HDI(-1))	0.21	1.40	0.18
L(ENC)	-0.28	-1.87	0.08**
L(ENC(-1))	0.46	2.85	0.01*
POPG	-1.25	-5.40	0.00*
POPG(-1)	1.277	5.23	0.00*
L(GFCF)	-0.04	-1.32	0.21
L(HHS)	-0.01	-0.16	0.87
L(HHS(-1))	0.05	1.18	0.26
L(EXPEN)	0.06	4.26	0.00*
L(EXPEN(-1))	-0.02	-1.39	0.19
C	-1.18	-0.79	0.44

Note: All variables are logged with the exception of POPg which is already in rate; *, ** Indicates significant at 5% and 10% level respectively. BG Test shows Breusch–Godfrey serial correlation test and BPG is the Breusch-Pagan-Godfrey Heteroskedasticity test.

The result from the ARDL estimation revealed (see Table 3) that previous values of economic development (HDI) were found to have a positive but insignificant impact on the current level of economic development. The current amount of energy consumption has a negative significant effect on economic development at 10% while the previous amount of energy consumption has a positive and significant effect on economic development in Nigeria at a 5% level of significance. 1 % increase in the previous year's energy consumption boost economic development by 0.46%. The negative effect of the energy consumption in the current effect is attributed to the low quality and quantity of energy. As revealed by Monyei, Adewumi, Obolo, and Sajou (2018), 40% do not have access to electricity. Also, the study of Ogbeide-Osaretin revealed that the use of coal and firewood which are not clean energy lead to about a 26% increase in poverty. Hence, energy consumption is having a negative effect on economic development in Nigeria. This result is consistent with the findings of Akomolafe and Danladi (2014) and Ekeocha et al. (2020).

The result also divulged that the current period of population growth and household size were found to have a negative significant effect on economic development as expected. The result revealed that a 1% increase in population growth and household size will lead to a 1.2% and 0.007% fall in economic development respectively in Nigeria. For population growth, the upshot is in agreement with the outcome of some studies (Ogbeide-Osaretin & Orhewere, 2020; Onwuka, 2006), but contrary to that Adewole (2012). The result of the impact of household size on economic development is in accordance with the result of Ogwumike and Ozughalu (2016); Ichoku et al. (2012) and Ogbeide-Osaretin. (2021) who found that household size increases poverty by 7%, seeing that poverty is a major characteristic of developing country. Government expenditure is a major country-specific variable. The coefficient revealed that it has a positive statistically significant effect on the economic development of Nigeria. Specifically, the result showed that a 1% increase in government expenditure result in a 0.06% boost in economic development in Nigeria. Capital captured by gross fixed capital formation revealed a negative insignificant effect on economic development. This is contrary to Solow's theory and expectation. However, the true picture of the low level of capital is shown. Data from the Central Bank of Nigeria Statistical Bulletin (2021) showed that a greater part of total government expenditure is allocated to recurrent expenditure than capital expenditure.

4.3.1.2. Result from Short-Run ARDL Establishment

As presented in Table 2, all the series were integrated of order one and zero for population growth at a 5% significance level. This is consistent with the assumptions of the ARDL-ECM. Thus, we proceed to carry out a co-integration test on the model using the bounds-testing approach of PSS. The result as presented in Table 1 (Appendix) confirms that there is a stable long-run relationship connecting the variables with an F-sat of 9.46 which is more than the upper bound of 3.79. Hence, the short-run dynamics are estimated and reported in Table 4. The diagnostic test was all found to be of a good standard, showing the good fitness of the model and robustness of the result.

Table 4. ARDL short-run estimation.

Dep. Var= Log(Economic Development (L(HDI))			
Method = ARDL; **Diagnostics :** R^2 = 0.69; **F-Stat.** = 4.79 **F-Pro.**= 0.01; **DW** = 1.74			
Independent Variable	**Coefficient**	**t-sat**	**Probability**
D(L(HDI(-1)))	0.04	0.27	0.79
D(L(ENC))	-0.34	-2.21	0.04*
POPG	0.01	0.13	0.90
D(L(GFCF))	-0.03	-1.09	0.29
D(L(HHS))	-0.01	-0.27	0.79
D(L(EXPEN))	0.05	2.69	0.02*
ECM(-1)	-1.01	-2.95	0.01*
C	-0.01	-0.07	0.94

Note: All variables are logged with the exception of POPg which is already in rate*Indicates significant at 5% level.

The results of the short-run ARDL turned out to be the same as that of the long-run ARDL model. Energy consumption was found to have a negative statistically significant effect on economic development in Nigeria. Thus, indicating that the consumption of energy is not relevant as a driver of economic development in the short run. Government expenditure showed a positive significant effect on economic development while population growth and gross fixed capital formation were found to have a positive and negative insignificant effect on economic growth respectively. The outcome of the impact of energy consumption on economic development is in agreement with the studies of Ekeocha et al. (2020). The error correction term (ECM) (Table 4) was found to behave appropriately, with a negative sign and significant at least at the 5% level. This suggests that changes in economic development from the short run converge over a long period every year.

Table 5. ARDL long run estimation of energy consumption.

Dep. Var= L(Energy consumption) (LENC)			
Method- ARDL; Selected Model= ARDL(1, 0, 1, 0, 0, 0) **Diagnostics : R^2** = 0.90; **F-Stat.** = 20.8; **F-Pro**.= 0.00; **DW** = 1.84; Pro (BG test): 0.79; Pro (BPG test)= 0.38; Pro (Ramsey test)= 0.18			
Independent Variable	**Coefficient**	**t-sat**	**Probability**
L(ENC(-1))	0.74	3.13	0.01*
L(HDI)	-0.72	-2.00	0.06*
POPG	-1.17	-1.94	0.07**
POPG(-1)	1.13	1.86	0.08**
L(GFCF)	-0.06	-1.44	0.16
L(EXPEN)	0.05	2.68	0.03*
L(OP)	0.01	0.50	0.62
C	2.30	1.179	0.26

Note: All variables are logged with the exception of POPg which is already in rate*, ** Significant at 5% & 10% level respectively. BG and BPG are as stated in Table 3.

4.3.2. Estimation of the Energy Equation

Table 5 showed that the previous values of energy consumption (ENC) have a positive and statistically significant impact on the current levels of energy consumption at a 5% significance level. Specifically, a 1% increase in the previous year's consumption of energy will lead to a 0.73% increase in the current year's consumption. The level of development revealed a negative and substantial impact on energy consumption. 1% increase in economic development will lead to a 0.71% fall in energy consumption. This is contrary to our expectations. However, given that the energy consumption in Nigeria is more non-modern energy (Monyei et al., 2018), it is expected that as the level of development increases, the consumption of this quality of energy will reduce for the consumption of higher quality of energy.

The current period of population growth was negatively related to energy consumption, contrary to expectation, while the previous year's levels of population were positively related to energy consumption in line with expectation, and both were significant at a 10% level of significance. The outcome of the linkage between energy consumption and population is contrary to the very few studies (Rahman, 2020). However as observed by Huang and He (2018) the increase in population leads to lower energy consumption as a result of the increased efficiency in energy from the densely populated areas and countries or the makeup of the demography.

Gross fixed capital formation also turned out not to have a significant impact on energy consumption just as the result of its impact on economic development. Government expenditure on the other hand turns out to be a very important factor to be considered in the consumption of energy in Nigeria. Oil price is positively related to energy consumption but was not significant and with a very small magnitude. The results thus revealed that the price of oil is not a major determinant of the consumption of energy in Nigeria.

4.3.2.1. Determination of a Long Run Relationship in the Energy Consumption Model

From the result of the unit root test, the model was subjected to the test to determine if there exists a long-run relationship among the variables. From the PSS bound testing result of F sat of f1.36122 which was lower than the lower bound of 2.62, and 2.26 at 5% and 10% levels of significance (see Table 2 of the Appendix), we failed to reject the null hypothesis of no long-run relationship existing among the variables of the model. Hence, policy recommendation on the energy consumption model is based on only the long-run estimation.

5. POLICY RECOMMENDATIONS AND CONCLUSION

5.1. Policy Implications

The nexus between economic development and energy consumption given population was examined in this study. Annual data on energy consumption, economic development measured by Human Development Index, and population growth among other variables. The following inference and recommendations were made:

1. The previous level of economic development increases the current level of economic development, however, not significant. Nevertheless, enhancing economic development in Nigeria requires a long-run policy measure.

2. Current and previous levels of energy consumption were found to be significantly related to economic development with a negative impact from the current levels of energy consumption both in the long run and the short run. This is particularly interesting as it shows that economic development cannot be attained in Nigeria without the supply of improved and stable energy. We, thus, counsel for the increase in the quality of energy such as the increase in the supply of electricity, for household cooking gas and solar for green energy. These will increase green industrial activities and increase the level of economic development in Nigeria.

3. As divulged by the result, the current period of population growth negatively and significantly impacts on economic development as expected and energy consumption only in the long run. Thus, we recommend the zealous pursuit of policy population reduction practically employing fertility reduction to enhance economic development.

4. Economic development had a negative substantial impact on energy consumption. Thus, while, it is important for the supply of modern energy for development, it is also important that the income level (development) be pursed affordability of modern energy.

5. Government expenditure was revealed to be a very vital factor in increasing economic development and the amount of energy consumption. As diverged by the result, government expenditure positively and significantly impacts economic development (both long-run and short-run) and energy consumption. Hence, we advocate for an increase in government expenditure, especially on human capital development (education and health). Also, government expenditure on the supply of energy supply (grid supply and other green energy sources) is strongly recommended.

6. Household size was revealed by the result to be negatively related to economic development both in the long-run and in the short-run. This also strengthens the outcome of population development. Hence, we advocate the enforcement of household size control.

7. Oil price which was introduced as a determinant of energy consumption was revealed not to have a significant impact on the consumption of energy in Nigeria. Hence, factors such as the income level of the people have been proven to be increased the consumption of energy to increase in Nigeria.

6. CONCLUSION

Energy is strongly believed to be vital for all economic activities and central to sustainable development. The population is also believed to be the source of human capital for economic development. Hence, it is expected that there is connectivity between energy consumption, population, and economic development. The main objective of this study is to investigate the linkage between population, energy consumption, and economic development in Nigeria. This study has however shown that there is a significant feedback impact between energy consumption and economic development in Nigeria. Population growth was found to be a connecting variable between the two, having a significant impact on energy consumption and economic development. Findings from the study also revealed that there is an important role for government to play in the achievement of economic development in Nigeria which is the use of its pattern of expenditure to increase economic development and consumption of stable and modern energy. It is therefore pertinent for effective population control to be put in place. An increase in the amount and welfare patterned government expenditure is strongly recommended for the achievement of economic development in Nigeria.

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APPENDIX

Table A1. Bounds testing cointegration result for Economic development equation.

ARDL Bounds Test Date: 02/20/22 Time: 18:42 Sample: 1996 2019 Included observations: 24		
Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	k
F-statistic	9.46	5
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Table A2. Bounds testing cointegration result for Energy consumption equation.

ARDL Bounds Test Date: 02/21/22 Time: 16:07 Sample: 1996 2019 Included observations: 24		
Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	k
F-statistic	1.36	5
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68