The Environmental Impact of Energy Consumption in Nigeria: Evidence from CO2 Emissions

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Research Article

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The Environmental Impact of Energy Consumption in Nigeria: Evidence from CO_2 Emissions

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Abstract

The consumption of energy to achieve economic growth has immensely impacted Nigeria's environment through its influence on CO_2 emissions. The paper employed Vector Error Correction Model (VECM) to analyzed the environmental impact of energy consumption in Nigeria using time series data from 1990-2018. Our study found a long run positive impact of GDP on CO2 emissions in Nigeria. This refute the Environmental Kuznet Curve hypothesis that environmental quality improved with an increase in income. We also found that charcoal consumption has a long run tendency of reducing CO_2 emission while fuel wood consumption has a long run possibility of raising CO2 emission. We also found that usage of gas oil has a negative impact on CO_2 emissions while natural gas consumption and fuel oil consumption has a detrimental impact on CO_2 emission. Hydroelectricity consumption on the other has a long run negative impact on CO_2 emission in Nigeria. However, we suggested for investment in hydroelectricity and wood biomass energy consumption that can minimize the potential environmental damage in Nigeria. Because hydroelectricity and biomass energy can substitute fossil fuel energy in the production of goods and services which can also help to mitigate CO_2 emissions and improve the environmental quality of the country.

Keywords: CO2 emissions, hydroelectricity, economic growth, population growth, charcoal consumption, gas oil consumption

1. Introduction

Nigeria's economy and its energy sector is extremely susceptible to fluctuations because of its over-reliance on fossil fuels, in particular oil and gas. It was argued that the inadequate policies and lack of professionalism in the new energy management put that country's energy grid in fragile to climate change (Akuru and Okoro, 2014). Nigeria exported around 774,000 million barrels of crude oil in 2014, with oil and gas accounted for 90% of exports and 15% of GDP (Africa, C. 2016). However, as a result of insufficient oil field infrastructure in the country, a substantial portion of these gases associated with oil production is flared into the atmosphere which stays there for a long time. Though the volume of flared has supplemented by over 50% over the past years according to the report (Africa, C., 2016). Nigeria nevertheless remains the world's fifth largest gas flaring nation (Africa, C. 2016) though the country is implementing projects in line with the Intended Nationally Determined Contribution (INDC) to minimize or remove GHG pollution from gas flaring by 2030. However, according to First Biennial Update Report (BUR I), the primary sources of energy in Nigeria are natural gas, oil and biomass (Federal Republic of Nigeria, 2018). Report show that the bioenergy share in 2020 is more than 80% of the total primary energy (Federal Republic of Nigeria, 2018). However, unfortunately, only about half of Nigeria's population has connections to grid-connected power. This is because the electric power supply in the country is insufficient and has limited industrial growth and development. For instance, the 2015 power supply averaged 3.1 gigawatts, an amount estimated to be a third demand (Federal Republic of Nigeria, 2018).

A 2018 report by Federal Republic of Nigeria declared that Nigeria vowed environmental degradation unreservedly to reduce GHG emissions by 20% by 2030, relative to business as usual (BAU) emission rate. Similarly, it was also reported that Nigeria's energy emissions increased by 32% on average from 1990 to 2014, mainly due to energy consumption especially fuel combustion (WRA CAIT 4.0, 2017). Though a fugitive emissions which occur from leaks and irregular release of non-renewable consumption, for instance, gases, are a significant source of GHG emissions but reduced recently according to recent statistics. While on the other hand, smaller sources of emissions from electricity and heating generation, transportation and manufacturing and construction have increased (WRA CAIT 4.0, 2017). But in 2016, energy efficiency increased by 20%, which provided 13-gigawatt renewable electricity to rural communities that are currently have no access to the electricity grid (African, 2016). Proportionally, crucial mitigation steps to end gas flaring by 2030 have been further established by the report. This involve the usage of efficient gas turbines, a 2% annual rise in energy efficiency, a shift in the mode of transport from automobiles to buses, a change in the power system, the development of climate-smart farming and forest conservation (the Federal Republic of Nigeria, 2018).

However, the relationships between energy, pollution and economic development thus have important policy consequences for any country's economic landscape. This is because economic development requires various quantities and forms of resources, like energy use. Thus, if CO_2 emission rate varies through various resource production and energy sources, the energy use and other resource production to achieve economic development ultimately adds to environmental quality. Energy consumption, mainly fossil fuel energy contributes to CO_2 emissions which is among the cause of climate change and global warming. Therefore, it was in line with this that the International Energy Agency (2018) suggested that any efforts to reduce CO_2 emissions in a country effectively, a strategic plan of the energy and economic sectors should be applied. The agency categorized energy users and producers of CO_2 emissions from energy burning into seven groups: industry, transportation, residential, commercial and private services, agriculture/forestry, fisheries, and undefined energy users (IEA, 2018). However, the carbon dioxide released into the environment from the usage of fossil fuels such as diesel, coal and natural gas is the key gas that induces the global warming (Yavuz, 2014).

Recently, energy consumption and environmental degradation has been the focus of intensive studies in the energy and environmental literature. Interestingly, scientific evidence to date remains controversial and unclear. The available research shows that empirical studies vary considerably in terms of data used and data analysis techniques and are not exhaustive in providing policy guidelines that can be implemented throughout nations (Kebede *et al.,* 2017). Studies over the past decades have revealed that energy has become one of the most vital drivers in the development process, particularly for its significant contribution to the industrial sector in many developing nation. This is because energy usage has a positive effect on the societal and national economy as well as the general well-being of the citizens on the one hand, and on the other hand, it harms the environment through indirect production of CO_2 emissions from energy incineration

Therefore, to study the environmental impact of energy consumption is necessary especially for a country like Nigeria with weak environmental regulations. This is because global warming is viewed as a major environmental challenge to climate change. In 2010, UNDP reported that most of the carbon emission is known to come from the production and consumption of non-renewable energy especially oil and gas. Therefore, since crude oil contributes significant percentage of Nigeria's GDP, using GDP as a measure of social and human welfare is unacceptable to a large extent. Because economic growth should also be achieved in a safe and sustainable economic environment to reduce the citizen's risks of exposure to various health hazards. Thus, this study seek to explore the environmental impact of energy consumption in Nigeria, evidence from CO_2 emissions.

The remaining parts of this research are organized as follows: section 2 review the related literatures while section 3 describes the materials and methods. Section 4 contains results and discussions, and section 5 presents the conclusion. Section 6 present recommendations and policy implications of the paper respectively.

2. Literature Review

The linkage between economic growth and CO_2 emissions has been examined by several researchers. For instance, Shahbaz *et al.* (2013) and Saboori and Sulaiman (2013) found a two-way relationship between GDP per capita and CO_2 emissions, while Alam *et al*. (2016); Hwang and Yoo (2012); Chandran and Tang (2013) and Saboori *et al*. (2012) found a one-way relationship between per capita GDP and CO_2 emissions. Also, in similar studies, Saboori *et al.* (2012), Saboori and Sulaiman (2013), and Alam *et al.* (2016) investigated the relationship between economic development and environmental degradation in Indonesian using the EKC approach. The result from Saboori et al. (2012) and Saboori and Sulaiman (2013) found that there is no evidence of the EKC hypothesis, while on the other hand, the evidence that support the EKC hypothesis was found by Alam *et al.* (2016) studies. Furthermore, studies by Farhani *et al.* (2014), Odhiambo (2011), Paresh and Narayan (2010), Kim, Lee, and Nam (2010), Kim and Baek (2011), Ghosh (2010) for instance, examined the links between economic growth and environmental pollutants. These studies confirmed the validity of the environmental Kuznets curve (EKC) Hypothesis, which states that an inverted U-shaped relationship between economic growth and the level of environmental degradation exists. This means that during the early stages of economic development, environmental destruction rises with the amount of per capita income and only falls with per capita income until hitting a plateau (Acaravci & Ozturk, 2010a).

Moreover, Apergis and Payne (2010b), Apergis and Payne (2014), Bella, Massidda and Mattana, 2014), Alkhathlan and Javid (2013), Saboori and Sulaiman (2013), Alam *et al*. (2016), Rafindadi (2016), Omri (2016) modeled the ties between economic development, energy use and emissions in the same context. These studies consider CO_2 emissions as a function of income, income squared, and income cubed in addition to other explanatory variables such as energy use; thus, the model suffered from collinearity problems. Therefore, our study is an attempt to fill the gap by introducing new variables such as fuel consumption, natural gas consumption, gas oil consumption, fuel wood consumption, hydroelectricity consumption etc. besides economic indicators such as GDP per capita. This is in order to solve the problem of omitted variables and misspecification of model.

Therefore, compared to previous research, our study has three significant contributions. First, beside the commonly used variables such as GDP per capita, this study considered energy consumption variables (such as natural gas consumption, fuel wood consumption, fuel consumption, charcoal consumption, and hydroelectricity consumption) as socioeconomic drivers of CO_2 emissions in Nigeria; this could provide exciting policy option to mitigate CO_2 emissions which has severe environmental impact. Second, unlike the other studies, this study employed Vector Error Correction model to investigate the environmental impact of energy consumption in Nigeria. The result from VECM will give an interesting direction to the policy makers not only in devising national policy related to energy consumption but also in developing and promoting a sustainable economic environment in the country. Thirdly, the relation between CO_2 emissions and economic growth in the energy demand system is explored to help the EKC hypothesis. This will address the study void in this area and is thus one of this research's main contributions.

3. Materials and Methods

According to Kebede *et al.* (2017), economic prosperity cannot take place without resource usage and, through the laws of thermodynamics, resource usage ultimately means waste output. Therefore, it's widely known that Nigeria depends mainly on fossil fuel consumption (petroleum and gas), which is a key driver of environmental damage and the severity of the impact of energy consumption on the Nigeria's environment depends on the energy consumption structure of the country. However, considering that Nigeria is abundant with fossil energy, the variables such as fuel oil consumption, natural gas consumption and gas oil consumption are included in the model. While other energy used in this paper is hydroelectricity as well as fuel wood and charcoal as other energy sources. All variables are in total energy consumption. Thus, the present study employed Vector Error Correction Model (VECM) to analyze the environmental impact of energy consumption in Nigeria. The data for the study were sourced from African Development Bank (2019) and National Bureau of Statistics (2019).

However, the choice of the variables follow some research suggestions such as International Energy Agency (2018) that suggested the categorization of the energy users and producers of CO_2 emissions from energy burning into seven groups, which include industry, transportation, residential, commercial and private services, agriculture/forestry, fisheries, and undefined energy users). In another study, Luong *et al.* (2017) observed that households consume more energy to complement their daily activities, especially in such areas as cooking, lighting and heating. Similarly, Baran & Yilmaz (2018) pointed out that energy is used and consumed more by the households' sector than in any other sector. While studies such as Azam *et al.* (2015a); Zhang, (2017) and Al-Fatlawi, (2018) have shown that electricity use and CO_2 emissions changes are associated with other economic measures, such as gross domestic products, exports, imports, international growth and foreign direct investment as well as energy consumption. While GDP per capita was used in order to capture the EKC hypothesis.

3.1 Models Specifications

3.1.1 Augmented Dickey-Fuller Unit root test

Since the data for this research possess the qualities of time series data, then it must be ensured that all the variables included in the model are stationary. If a time series is not stationary in the sense just defined, it is called a non-stationary time series. In other words, a non-stationary time series will have a time-varying mean or a time-varying variance or both. This also ensures that every variable has a constant mean-variance. This will make the prediction of future value sensible and meaningful. Therefore, if a variable is non-stationary at level, the data will be differenced. The researcher will expose the research data to a stationary test based on the Augmented Dickey Fuller test.

The test will be based on the following general model for the ADF unit root framework:

With constant only: $$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + \alpha_i + \varepsilon_t \quad (1)$$

With Trend and Constant: $$\Delta Y_t = \beta_1 + \beta_{2t} + \delta Y_{t-1} + \alpha_i + \varepsilon_t \quad (2)$$

No Trend, No Intercept: $$\Delta Y_t = \delta Y_{t-1} + \alpha_i + \varepsilon_t \quad (3)$$

Where Y_t means the level of variable, u_t is the stochastic error term which is expressed as the independent and identically distributed error term with constant variance and zero mean which is often referred to as white noise error term. Suppose Y_t is regressed on its first lag value Y_{t-1} and when the estimated $(Y_{t-1}) = 1$ and $\beta = 1$, the series is said to be non-stationary and when $\beta > 1$ is also said to be non-stationary. However, when $\beta < 1$, the series is stationary, but if $\beta = 0$ or $\beta > 1$, we may reject the null hypothesis against the alternative at the significance value, therefore our residence is I(1).

3.1.2 Vector Error Correction Model

The paper examine the short-run and long-run impact of energy consumption in Nigeria using Vector Error Correction model. Thus, owing to the fact that all the variables employed in this study have time series qualities and are integrated at first difference, i.e. I(1) series, the Vector Error Correction Model (VECM) was employed to analyze the short-run and long-run impacts of energy consumption on Nigeria's environment proxy by total CO_2 emissions. The conventional VECM is written compactly as:

$$\Delta Y = \sigma + \sum_{i=1}^{k-1} \gamma \Delta Y\mathrm{t} - 1 + \sum_{1=1}^{k-1} \eta \Delta X + \sum_{1=1}^{k-1} \Phi \Delta R + \lambda ECT + \mu \quad (4)$$

Where ECT_{t-1} = lagged OLS residual obtained from the long-run cointegrating equation.

$$Y_t = \boldsymbol{\sigma} + \eta_j X_t + \xi_m R_t + \boldsymbol{\mu}_t \quad (5)$$

and express as;

$$ECT_{t-1} = [Y_{t-1} - \eta_j X_{t-1} - \xi_m R_{t-1}] \quad (6)$$

λ= coefficient of the ECT and the speed at which Y returns to equilibrium after changes in X and R.

The specific VECM for this studies are as follows:

$$\Delta CO2t = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (7)$$

$$\Delta GDPPt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (8)$$

$$\Delta CCCt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (9)$$

$$\Delta FWCt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (10)$$

$$\Delta FOCt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (11)$$

$$\Delta NGCt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (12)$$

$$\Delta GOCt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (13)$$

$$\Delta HYDt = \sigma + \sum_{i=1}^{k-1} \alpha i \Delta \mathrm{CO2t} - 1 + \sum_{m=1}^{k-1} \Phi m \Delta GDPPt - 1 + \sum_{n=1}^{k-1} \eta n \Delta CCCt - 1 + \sum_{p=1}^{k-1} \varphi p \Delta FWCt - 1 + \sum_{q=1}^{k-1} \xi q \Delta FOCt - 1 + \sum_{r=1}^{k-1} \theta r \Delta NGCt - 1 + \sum_{s=1}^{k-1} \Upsilon s \Delta GOCt - 1 + \sum_{w=1}^{k-1} \delta w \Delta HYDt - 1 + \lambda ECT + \mu \quad (14)$$

The rationale behind adopting this model is that empirical studies have shown that the VECM is best suited for model estimation when economic variables are individually cointegrated, i.e., when there is an excellent long-run relationship between them. Another advantage is that it combines both the short-run dynamic and long-run equilibrium models in a simplified and unified system. At the same time, it guarantees conceptual rigor, accuracy and integrity of data.

3.2 Summary of Data Used.

The minimum total emitted CO_2 is 68,581 metric tons per capita and the maximum emitted CO_2 is 106,124 metric tons per capita. The average CO_2 emission was 90,738.35 metric tons per capita (Table I). The average CO_2 emission from transport is 47.1943 metric. The average hydroelectricity consumption is 6,006.462 million kilowatts per hour while the maximum consumption was 8,234.1 million kilowatts per hour, and the minimum was 4,387 million kilowatts per hour (Table I). Nigeria consumed a maximum of 3,295 thousand metric tons of fuel oil annually and a minimum of 406 thousand metric tons per annually. The average consumption of diesel oil was 1,588.038 thousand metric tons (Table I).

The average fuel oil consumption in Nigeria annually was 2,025.385 metric tons according to our findings (Table I). Also, the country consumed a maximum of 1,660,131 terajoules of Natural gas, including LNG and a minimum of 152,000 terajoules. The average production of natural gas in Nigeria was 766,348.1 terajoules (Table I). On the other hand, the production of gas oil/diesel oil reaches a maximum of 2,604 thousand metric tons with the lowest of it' kind of 294.

4. Results and Discussions

4.1 ADF Test Result

Based on the result obtained from the Augmented Dickey Fuller unit root test (Table II), all the variables are integrated of order one, indicating that they were not stationary at levels and this is because the critical values of the ADF test statistics at 1%, 5% and 10% level of significance, are in all cases greater than the Augmented Dickey-Fuller (ADF) test statistics. Therefore, in conclusion, all the variables in the model they are integrated of order one and thus, there is a need to check both the long run and the short run relationship that exist among the variables and estimate the error correction model.

4.2 Vector Error Correction Model Estimating the Short-run and Long-run Effect of Energy Consumption on Nigeria's Environment proxy by Total CO_2 Emissions in Nigeria.

The short-run and long-run influence of energy consumption on Nigeria's environment through total CO_2 emissions were estimated using the vector of error correction model and the normalized estimation. The result from the error correction model (Table III) estimated the speed at which the errors that occurred in the short-run period will be corrected. The normalized estimated result (Table IV), on the other hand, explained the long-run influence of energy consumption on Nigeria's environment through total CO_2 emissions.

The adjustment term (-0.1965) from the estimated result is not statistically significant (Table III). This suggests that the previous year's deviation from the long-run equilibrium is corrected for within the current year at a convergence speed of 19.65%. That is, in the long-run, the discrepancy found in the short-run lags difference will be adjusted and converged back to equilibrium at a speed of 19.65%. But this has no statistical significant meaningful.

On the other hand, the result from Table IV shows that in the long run, GDP has a significant long-run tendency of reducing the total CO_2 emissions in Nigeria. This result confirmed the validity of the Kuznets Curve (EKC) hypothesis for the climate, which posits an inverted U-shaped association between the degree of environmental destruction and income development. The research also agreed with the suggestion that during the early stages of economic development, environmental destruction rises with the amount of per capita income and only decreases with per capita income increase after reaching a plaeteau (Acaravci and Ozurk, 2010a). The finding also confirmed the studies by Ben Youssef et al. (2016) that higher income level reduces CO_2 emissions.

The result show that charcoal consumption has a significant possibility of reducing total CO_2 emissions in the long-run. The reason is as a result technological improvement in the country manufacturing and construction sector and the change in the method of cooking in the residential buildings in the cities. While fuel wood consumption has a long-run possibility of rising the total CO_2 emissions. This is because fuel wood is the primary energy used for cooking and heating by the majority of Nigerian population, especially in rural areas and the current rate of fuel wood consumption in Nigeria has a potential of reducing environmental quality in the future. This has put more threat to Nigeria's environment. Similar study also found that emissions were entirely from degradation and loss of forest land (FOASTAT, 2018). This finding refutes Sulaiman et al. (2020) findings which argued that CO_2 emissions declined with an increased in wood biomass consumption.

Furthermore, gas oil consumption has a significant possibility of reducing total CO_2 emissions in the long-run. This is because recently houses and residential buildings in Nigeria especially rural areas often use gas oil to help in setting fire for cooking, local lightning and heating, especially during the rainy season. Therefore, as a result of this, the level of emitted CO_2 in our buildings contributed in reducing the level of environmental quality in the country. The study finding accord with a recent study by Dong, *K. et al*. (2017) that gas consumption reduces CO_2 emissions but refutes the report by IEA (2018) that residential, commercial and private services were among the energy users and producers of CO_2 emissions from energy combustion as well as the reports by UNDP (2010) that most of the carbon emission is known to come from the production and consumption of non-renewable oil and gas.

The result also show that natural gas consumption has a significant positive effect on total CO_2 emissions. This signifies that an increase in natural gas consumption has a possibility of rising Nigerian total CO_2 emissions in the future. Also, the implication of the finding is that increasing consumption of natural gas has the potential of threatening Nigeria's effort to meet the global goal for O_2 emission reduction as outlined in the 2015 Paris Climate Change Conference. This findings refutes the hypothesis that even though refining of natural gas increases CO_2 emissions, it produces 50% less carbon into the atmosphere than other fossil fuels such as coal and petroleum.

Also, the result show that an increase in fuel oil consumption in the long run, will increase total CO_2 emission. Similar studies also found that more fuel oil consumption accelerates CO_2 emissions in Nigeria (see Sulaiman *et al.,* 2020; and Apergis and James, 2010a). Hydroelectricity consumption on the other hand has a significant negative long-run effect on total CO_2 emissions. This signifies that hydroelectricity has the tendency of reducing total CO_2 emissions in Nigeria and improve the country's environmental quality. With this result, it signifies that the increasing needs for clean and economic environment is necessary in Nigeria and the country will have to work hard to promote the development of cleaner transition energy such as hydroelectricity in order to meet the demand for optimal energy consumption structure as well as improving environmental quality in the country.

Note that, based on the above results, GDP, charcoal consumption, fuel wood consumption, gas oil consumption, natural gas consumption, fuel oil consumption and hydroelectricity consumption have asymmetric effects on total CO_2 emissions in the long run on average ceteris paribus (see Table IV).

5. Conclusion

The paper explored the environmental impact of energy consumption in Nigeria evidence from CO_2 emission. Though energy consumption in Nigeria played a vital role in promoting the growth of the country's economy, our study also found that it has a significant impact on the country's environment through its influence on the level of CO_2 emission. This is because the level of CO_2 emissions in Nigeria was found to be indirectly reflecting the social and economic development in the country. As a result of this, we suggested for the need in the upgrade of energy use in an environmental way such as shifting to a more technological way, for instance, a solar source of energy and hydroelectricity. This also means that Nigeria's economic growth requires extensive–scale energy exploitation and utilization. After all, the deposited fossil energy is not enough to satisfy the needs of over 200 million Nigerian population and its economic growth. Therefore, this requires excellent improvement in energy efficiency and the development of new energy consumption structure such as renewable energy like solar energy, which should be the long-run potentials of growth, development and sustainability. This is because the implication of long-run impact of shifting to renewable energy resources in Nigeria is zero emissions economy, health costs reduction by lowering environmental pollution and climate change mitigation. Nigeria's fossil fuel-based economy will depleted one day and therefore, the need for capital investment in searching for alternatives earlier is of utmost importance because in the long-run, Nigeria needs more carbon space to meet the global standard for developmental needs.

Furthermore, our empirical findings confirm the Environmental Kuznets Curve (EKC) theory for the climate change, which posits that higher income can reduce the level of environmental pollutions in the country after reaching a threshold. This shows that CO_2 emissions in Nigeria could be significantly reduced in the long run when the environmental pressure such as deforestation is reduced as well as strengthening the environmental policy of the country. This can guarantee sustainable development and environment in Nigeria through a robust policy implementation by the concerned authorities.

6. Recommendations and Policy Implications

Based on our findings, the study recommends more investment in hydroelectricity and wood biomass energy consumption that can improve the country environmental quality and reduce the potential of CO_2 emissions in the country with cleaner economic environment in the future. This can help in achieving energy security and reduce the over-dependence on other polluting energy sources such as fossil fuel like fuel, natural gas and gas oil. Furthermore, since fossil fuel consumption has proven significant drivers facilitating CO_2 emissions in Nigeria according to our findings, hydroelectricity and fuel wood consumption through biomass energy can substitute fossil fuel energy in large scale which can also be used in the production of goods and services as well as mitigate the level of CO_2 emissions in the country. Therefore, Nigeria can promote the efficiency as well as the sustainability of hydroelectricity and biomass energy consumption to achieve energy security and reduce dependency on the oil-based economy. This can also have a positive impact in diversifying the country's economy to renewable and cleaner economic environment with good energy strategy.

Also, there is an urgent need to improve the heating system and electricity grid in the country, though recently there is implementation of a smart agricultural system that mitigates climate change by some Governors of the States especially Rivers State and the recent massive reforestation in most of the States of the Federation. Therefore, this clearly show that Nigeria have the potential of achieving clean energy consumption target through efficient utilization of the country's abundant energy.

Furthermore, while striving to mitigate the environmental problems by promoting hydroelectricity and biomass energy, it is essential to note that cleaner economic growth with good environmental quality should be compromised. This is because the source of hydroelectricity is water and the source of wood biomass is trees which if unsustainably used and harvested can cause environmental degradation due to forest destruction, which can harm the economic environment of Nigeria. Therefore, the study suggest for the improvement in Nigeria's environment through reduction in deforestation as well as strengthening the environmental policy of the country. This can guarantee a cleaner and safe economic environment in Nigeria.

Also, the need for robust policy implementation by the concerned authorities must be pursued in order to promote and improve the environmental quality that can suit the growth of the economy without trading off the future fate of Nigeria's environment generation. Therefore, the need for energy development program that can reduce the massive dependence on fossil fuels such as oil and shift to more cleaner and renewable energy is necessary. The government should also invest more on technology for promoting the development of new energy resources and renewable energy sources since Nigeria has enough quantities of untapped renewable energy. However, to reduce the reliance on fossil fuel consumption and wean from an oil-based economy, the Nigeria must create incentives to the renewable energy sector, for instance, the power holding company of Nigeria.

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Ethical Approval

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Not Applicable

Authors Contribution

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Availability of data and materials

The data will be available on request

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