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Does Natural GasConsumption Enhance a Sustainable Environment in Africa? Empirical Evidence using Panel Analysis

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ABSTRACT:- This effect of natural gas on environmental sustainability among selected African countries was examined in this study. The six selected African countrieswere: Angola, Algeria, Egypt Ghana, Libya, and Nigeria and the study cover the period 1990-2022. To achieve the purpose of this study natural gas consumption was analysed along with foreign direct investment, credit to the private sector, population growth rate, GDP per capita and trade openness to determine their impact on environmental performance index and carbon emission per capita (proxy for environmental sustainability) using panel analysis. Based on the analysis of the data using panel fixed effect regression econometric technique, some key empirical findings were made. Egypt had the highest environmental performance index (EPI) and per capita carbon dioxide (CO2) emission. Algeria consumed more of natural gas than any of the countries selected for the study. Direct relationship between the natural gas consumption and environmental performance index (EPI) was visualised in Algeria, Egypt and Nigeria. Natural gas consumption had a negative and significant impact on the environmental performance index while natural gas consumption had a positive and significant impact on CO2 emission per capita. FDI was found to significantly improve environmental performance while trade openness also improves the performance of the environment but marginally. GDP per capital and credit to the private sector were found to retard environmental performance index in Africa. The study further found that FDI and GDP per capita contributed to environmental degradation significant while credit to the private sector and trade openness marginally destroyed the environment in terms of CO2 emission per capita. Only population growth rate was found to significantly reduced CO2 emission in Africa.Consequent upon the findings, the study concludes that a variation exists in the relative impact of natural gas consumption on environmental sustainability among the selected African countries and that natural gas consumption will more likely be consistent in improving environmental quality and sustainability in Africa. Based on the findings and conclusion, the study recommends: increase investment in natural gas production, consumption and renewable energy by African countries especially renewable energy in order to improve and sustain the environment.

Key words: Natural gas consumption, environmental performance index, carbon emission per capita and Environmental sustainability.

I. INTRODUCTION

Energy consumption especially, natural gascould be ascribed as a disparity index among African countries. This is because most African countries are bedeviled by lack of basic energy infrastructure despite abundant energy resources.This not only stunts developments in human capital but also growth of enterprises and national development. Access to modern energy services is crucial for sustained development in advanced economies. However, many African nations face substantial challenges in making energy available and accessible to both business and the people. More than two-thirds of African nations lack access to electricity, and the majority rely on unsafe and inefficient cooking method in spite of the availability abundant natural gas in the continent.

Solid biomass, mostly fuel wood and charcoal are the dominant sources of energy, surpassing all other fuels combined. Additionally, the average per capita electricity usage is insufficient to sustain the continuous operation of a single 50-watt light bulb. Africa has a wide energy portfolio and is one of the top crude oil and natural gas producers in the world, but 70 percent of its populace lives in poverty. Due to problems in the energy industry, almost 40% of the population in certain African countries does not have access to power. The poor service has affected everyone, including those with power. According the African Development Bank (2015) about 645 million people in Africa have no access to electricity while about 700 million have no access to clean cooking energy. Most African households use biomass for cooking and about 600,000 people die from the resultant indoor pollution. The implication of lack of access is that energy availability and affordability (usage) is very marginal compared with the more developed countries. The ADB further found thatper capita electricity consumption in Africa is 181 kWh on the average compared with 13,000 kWh in the United States and 6,500 kWh in Europe. Power cuts and energy bottlenecks add to the problem.

A substantial portion of the continent especially the rural communities lack connectivity to the power grid. Therefore, the limited availability of reliable and cost-effective energy resources continues to be a major obstacle to the progress of human, social, and economic growth in Africa (Mmbaga, Kulindwa& Kazungu 2023). However, the degradation of the environment in Africa is a substantial obstacle that is worsened by the simultaneous impact of energy use and economic expansion. A substantial number of African nations heavily depend on fossil fuels, comprising coal, oil, and natural gas, to fulfil their energy requirements.
The extraction, manufacturing, and combustion of these fuels result in the emission of pollutants into the air and water, leading to the degradation of habitats and the exacerbation of climate change. As the need for energy increases in tandem with economic expansion, there exist a corresponding increase in the urgency to utilise fossil fuel reserves, ensuing in additional degradation of the environment in numerous African nations. Furthermore, economic endeavours in African nations, i.e. farming, timber extraction, mineral extraction, and the construction of infrastructure, frequently lead to the destruction of forests and the deterioration of soil quality. Deforestation diminishes biodiversity and ecological services, while also intensifying climate change through the discharge of carbon stored in trees.

The rise in energy use, particularly in industrial sectors, together with economic advancement, frequently upshots in degradation of the environment in Africa.

Igbru and Ifurueze (2021) assert that Africa encounters numerous obstacles concerning energy consumption and growth of the economy, which converge to exacerbate degradation of the environment. Many African nations face challenges in providing sufficient access to contemporary energy services, especially in rural regions. A substantial number of individuals in sub–Saharan Africa depend on conventional biomass for the purpose of cooking and heating, ensuing in the occurrence of indoor air pollution and associated health problems. Africa has a plentiful supply of energy resources, i.e.crude oil, natural gas, coal, hydro, solar, and wind. Nevertheless, the allocation of these resources is frequently imbalanced, ensuing in discrepancies in energy availability, economic growth and perhaps environmental sustainability.Therefore, in order for Africa to make progress in terms of the environment, access to cleaner energy must therefore be enhanced significantly if the continent is to meet the Sustainable Development Goals (SDGs), especially Goal 7 on universal access to affordable, reliable and modern energy services, and the reduction of CO2 emissions.

It should be noted that despite Africa's low access to energy, its environment tends to suffer some of the worst environmental problems.It is therefore crucial to comprehend and forecast both energy consumption and environmental challenges, along with their sway on overall environmental sustainability and specific aspects of it, i.e. the environmental performance index and CO2 emission per capita. This statement provides the rationale and impetus for doing the investigation.We shall continue our research by reviewing relevant literature, followed by procedure employ to achieve the purpose of the study, presentation of results and concluding remarks.

II. LITERATURE REVIEW

Hosier and Dowd (1987) and Leach (1992) proposed the Energy Transition theory, which relates the type of energy utilised to the income level. Moving away from traditional, fossil fuel-based energy sources and towards more sustainable, renewable ones is the goal of energy transition theory, which provides a framework for studying and comprehending this process. Cleaner, more efficient, and ecologically sustainable energy systems are the focus of this theory, which also delves into the dynamics, obstacles, and potential benefits of this transition. In an effort to decipher the intricate interplay and metamorphosis taking place inside energy systems through time, energy transition theory incorporates a wide range of aspects, comprising technical, economic, social, political, and environmental considerations.

Many believe that energy is a key factor propelling the modern economy, particularly in nations that have had tremendous expansion in the past several years. As the theory elucidates, a nation's energy consumption pattern is very sensitive to its per capita income. This idea, which takes its cues from consumer theory, proposes that, as disposable income rises, people would switch from utilising older, less efficient forms of energy to more modern, more convenient ones. Nations with higher incomes are believed to use more high-quality energy than those with lower incomes, in assent with this notion. The inability to access modern energy sources also hinders a nation's chances of reducing poverty and achieving sustainable development, in assent with the Energy Transition theory. Since energy deprivation hinders productivity and limits level of economic activities, ensuring access to energy is crucial to any effort to reduce poverty (Pachauri & Spreng, 2004; Kaygusuz, 2011; Sovacool, 2012).

One of the most imperative parts of the theory of energy transition is the environmental Imperatives which arguesthat societies should immediately begin to transition to sustainable energy systems in order to address pressing environmental concerns that is reducing pollution in the air and water, protecting biodiversity, and conserving scarce resources. Combustion of fossil fuels endangers ecosystems, human health, and the global climate system via contributing to air pollution, environmental degradation, and greenhouse gas emissions. To lessen these adverse effects on the environment and accomplish sustainability targets overtime, it is essential to switch to renewable energy and implement energy efficiency measures. It should be noted that despite the clamour for countries to transit from the usage of fossil fuel to renewable energy, sub–Saharan Africa seems to be cut off from the web of energy transition due to lack of political will, dearth of energy infrastructure and low level of investment in other energy sources. Also, crude oil (fossil fuel) remains one of the major revenue sources for most African countries hence trading off her major source of survival for an unknown source appears to be difficult.

Myriad of empirical literature abound on the effect of energy consumption on the environment. Abdulkarim (2023) examined the dynamic effects of energy consumption, economic growth, international trade and urbanization on environmental degradation in Nigeria using annual time series data covering the period 1980 to 2020. The study used the Autoregressive Distributed Lag technique in the presence of structural breaks for its data analysis. The empirical findings support the existence of environmental Kuznets curve hypothesis for Nigeria in the long and short run. Energy consumption and total import exacerbates environmental deterioration in the long and short run, whereas total export improves environmental quality in the long and short run. Financial development, which contributed to a conspicuous decrease in the level of environmental destruction in the long run, escalated it in the short run. In contrast, urbanization caused a significant increase in environmental damage in the long run but motivated a decrease in biodiversity loss in the short run.

Haliru (2023) studied the effect of energy used on green growth in Nigeria, with a focus on renewable energy using data sourced from the WDI and IEA over the period 1980-2021. The study adopted the Autoregressive Distributed Lag Model (ARDL) to investigate the influence of energy consumption and selected variables such as Foreign Direct Investment (FDI), Openness (OPN), and Carbon Tax (C02 tax) on Green Growth in Nigeria. The findings from this research revealed that green growth has a statistically significant positive relationship with its first lag and current value at a 1% level of significance. Furthermore, it was discovered that there is a positive and statistically significant relationship between electricity (energy) consumption and green growth in Nigeria. However, the results indicated a negative and statistically insignificant relationship between foreign direct investment and green growth. Based on these results, the study recommended that government pays more attention to the development of renewable energy sources.

In another study by Oladipupo, et al. (2022) on the impact of globalization and renewable energy consumption on environmental degradation: A Lesson for Developing Nations, the authors employed a novel quantile on quantile regression (QQR) method, emphasizing its non-linear advantages over conventional linear approaches. The dataset used for analysis spans from 1970 to 2018. The findings suggests that nonrenewable energy use, globalization, and economic growth contribute to environmental degradation across most quantiles, indicating their significant roles in the decline of environmental sustainability in South Africa. They also reported that the impact of renewable energy use on CO2 emissions appears to be weak across all quantiles. This highlights the insufficient contribution of renewable energy sources to meeting environmental sustainability requirements in the country.

Qudrat-Ullah and Chinedu, (2021) reported their study on quantitative assessment of the impact of renewable energy consumption and environmental sustainability on economic growth across Africa. Utilizing a panel dataset encompassing thirty-seven African nations, and employing the system Generalized Method of Moments (GMM) estimation technique, the results of their research suggests that the adoption and development of renewable energy sources have a positive influence on economic growth in Africa, both in the short run and the long run. The study furthered that, a one percent increase in renewable energy consumption is associated with a 0.07% increase in short-term economic growth and a more substantial 1.9% increase in long-term economic growth. The research concluded that environmental sustainability, as measured by a reduction in emissions (CO_2), may not currently be a top priority for Africa's comprehensive development efforts, is based on the statistical insignificance of the coefficient related to CO_2 emissions in the analysis.

Amoah, et al. (2020) investigated the role of economic well-being and economic freedom as drivers of renewable energy consumption using the share of renewables in total energy consumption in Africa. Employing the Dynamic Ordinary Least Squares econometric technique to analyze panel data of 32 African countries over the period 1996-2017. the study provided evidence that increasing economic well-being in Africa increases the share of renewables in total energy consumption to a point after which it turns negative (inverted U shape). Second, the disaggregated measures of economic freedom show that both property rights and tax burden decrease the share of renewables in total energy consumption. On the contrary, an increase in trade freedom and business freedom measures increases the share of renewables in total energy consumption. Toward the goal of promoting access to affordable, reliable, sustainable, and modern energy for all by 2030, governments in Africa should actively encourage trade freedom and business freedom to enhance the share of renewable energy consumption. Similarly, reducing the tax burden will promote the share of renewable energy consumption. Likewise, we call for further investigation into our evidence of a negative relationship between property rights and the share of renewables in total energy consumption

Muhammad, Muhammad and Muhammad (2020) investigated the nexus between energy consumption, economic growth and CO2 emission in Pakistan by using annual time series data from 1965 to 2015. The estimated results of ARDL indicated that energy consumption and economic growth increase the CO2 emissions in Pakistan both in short run and long run. Based on the estimated results, it was recommended that policy maker in Pakistan should adopt and promote such renewable energy sources that will help to meet the increased demand for energy by replacing old traditional energy sources such as coal, gas, and oil. Renewable energy sources are reusable that can reduce the CO2 emissions and also ensure sustainable economic development of Pakistan.

Nwatu and Ezenwa (2020) estimate the relationship between natural gas consumption, economy growth and carbon (iv) oxide emission using time series data between 1980 to 2016. Using the Vector Autoregressive (VAR) model estimation. The VAR was also applied in the impulse response and variance decomposition anlaysis of the different variables to natural gas consumption shocks. The results coefficients for the multi-directional relationships between natural gas consumption, economic growth and carbon dioxide emission were obtained in the short run for Nigeria. A unidirectional Gragner Causality relationship was also determined between GDP and the other variables. Conclusions and policy recommendations were then made to the government in line with the results of the model estimation. Top of the list is the investment in the natural gas utilization network to increase natural gas consumption which would reduce the impact of other fossil fuels as well as serve as a transition fuel in our effort towards sustainable energy sources.

Khan and Rehan (2020) investigated the relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan using annual time series data from 1965 to 2015. The estimated results of ARDL indicated that energy consumption and economic growth increase the CO_2 emissions in Pakistan both in short run and long run. Based on the estimated results, the study recommended that policy maker in Pakistan should adopt and promote such renewable energy sources that will help to meet the increased demand for energy by replacing old traditional energy sources such as coal, gas, and oil. Renewable energy sources are reusable that can reduce the CO_2 emissions and also ensure sustainable economic development of Pakistan.

Nkengfack and Fotio (2019) analyzed the cointegration and the causal relationship between energy consumption, economic growth and carbon emissions, using aggregate and disaggregate measures of energy consumption for Algeria, Egypt and South Africa over the period 1971-2015. Based on the ARDL bounds testing approach adopted, the results of the study showed that aggregate energy consumption and economic growth have positive and significant impacts on carbon dioxide (CO_2) both in the long and short run in those countries. At the disaggregated level, the main energy-related drives of carbon emissions are oil, electricity and coal consumption in Algeria, Egypt and South Africa, respectively. In addition, the implementation of the Toda-Yamamoto test for causality revealed the existence of several types of relationship between CO_2 emissions, economic growth and energy consumption.

Mallesh and Asharani (2019) examined the role of natural gas and renewable energy consumptions on CO2 emissions and economic growth during 1965-2016 within a multivariate framework. The autoregressive distributed lag bounds testing approach to cointegration and vector error correction model (VECM) is employed to explore the long-run and causal nexus among the natural gas consumption, renewable energy consumption, coal and petroleum consumption, CO2 emissions, and economic growth, respectively. The empirical results showed existence of long-run equilibrium association among the variables. The Granger causality results indicated that the short-run bidirectional causality between renewable energy consumption and economic growth in India, while no causality is found between these two variables in China. However, natural gas consumption causes economic growth in China whereas no causality is confirmed in India in the short-run. The findings further suggested that there is long-run bidirectional causality among the considered variables in both countries. The study finally addressed several important policy implications.

Isik, Ongan and Özdemir (2019) investigated the impact of real GDP, population, and renewable energy and fossil energy consumptions on CO2 emissions in ten US states from 1980 to 2015. The examined results indicated that the EKC hypothesis is valid for the following states Florida, Illinois, Michigan, New York, and Ohio. The results indicated that fossil energy consumption have negative impacts on CO2 emission levels in Texas while energy consumption having positively influence on CO2 emissions in Florida but this impact is lower as compared to other states of US.

Hanif (2018) studied the influences of economic growth; urban expansion; and consumption of fossil fuels, solid fuels, and renewable energy on CO2 emission in Sub-Saharan Africa economies from 1995 to 2015 by utilizing the GMM model for examination of the association among the study variables. The examined results indicated that consumption of fossil and solid fuels positively impact the CO2 emissions while renewable energy helps to decrease the CO2 emissions.

Boontome et al. (2017) conducted a study focused on Thailand, aiming to explore the causal connections among various forms of energy consumption, CO_2 emissions, and economic growth. By analyzing yearly data spanning from 1971 to 2013, the researchers established the presence of cointegration and identified a causal relationship where non-renewable energy consumption influences CO_2 emissions. As a result of their findings, the authors suggested that Thailand should prioritize an expansion of its utilization of renewable energy sources. This transition can have implications for environmental sustainability and economic development in the country.
The above literature provide evidence that a lot of studies have been done on the effect of energy use and environmental sustainability both at the country and regional level. However, most of the works consulted here at the regional level were done in Asia and America and were more concerned with fossil fuel and environmental degradation. Given the critical position natural gas consumption play in the growth and environmental sustainability of nations due to its availability, affordability and environmental friendliness, it is therefore imperative to examine how Africa has fared in the natural gas consumption and environmental sustainability mix.

III. METHODOLOGY

The analytical foundation of this study is base on the energy transition theory by Hosier and Dowd (1987) and Leach (1992) and the work by Abdulkarim (2023). The theorylinks the type of energy utilised to the income level. Moving away from traditional, fossil fuel-based energy sources and towards more sustainable, renewable ones as income increases. Natural is seen as a transition energy due to its environmental friendliness and affordability. The work of Abdulkarim (2023) which explored the link between energy consumption and environmental degradation is also very vital in the formation of the model for this study. However, the present study shall deviate from earlier studies in terms of the variables, scope and time frame. The study shall focus on the consumption of natural gas on environmental sustainability. The natural gas consumption mix shall incorporate foreign direct investment, credit to the private sector, trade openness, population growth and GDP per capita while environmental sustainability is captured by environmental performance index and carbon emission per capita. Consequent on this background, the models for this study are stated thus:

$EPI = f\,(NGC, FDI, CRED, TROPEN, GDPPC)$ (1)

$CPC = f\,(NGC, FDI, CRED, TROPEN, POPL, GDPPC)$ (2)

Equations (1) and (2) are transformed into econometric models as follows:

$EPI_t = \beta_0 + \beta_1 NGC_t + \beta_2 FDI_t + \beta_3 CRED_t + \beta_4 TROPEN_t + \beta_5 GDPPC_t + \mu_t$ (3)

$CPC_t = \beta_0 + \beta_1 NGC_t + \beta_2 FDI_t + \beta_3 CRED_t + \beta_4 TROPEN_t + \beta_5 POPL_t + B_6 GDPPC_t + \mu_t$ (4)

Equations (3) and (4) are transformed into pool effect model as follows:

$EPI_{it} = \beta_0 + \beta_1 NGC_{it} + \beta_2 FDI_{it} + \beta_3 CRED_{it} + \beta_4 TROPEN_{it} + \beta_5 GDPPC_{it} + \mu_{it}$ (5)

$CPC_{it} = \beta_0 + \beta_1 NGC_{it} + \beta_2 FDI_{it} + \beta_3 CRED_{it} + \beta_4 TROPEN_{it} + \beta_5 POPL_{it} + B_6 GDPPC_{it} + \mu_{it}$ (6)

Equations (5) and (6) are transformed into fixed effect models as follows:

$EPI_{it} = \beta_0 + \beta_1 NGC_{it} + \beta_2 FDI_{it} + \beta_3 CRED_{it} + \beta_4 TROPEN_{it} + \beta_5 GDPPC_{it} + \sum_i^9 = 1\alpha_i idum\varepsilon 1_{it}$ (7)

$CPC_{it} = \beta_0 + \beta_1 NGC_{it} + \beta_2 FDI_{it} + \beta_3 CRED_{it} + \beta_4 TROPEN_{it} + \beta_5 POPL_{it} + \beta_6 GDPPC_{it} + \sum_i^9 = 1\alpha_i idum\varepsilon 1_{it}$ (8)

Equations (7) and (8) are transformed into Random Effect model as follows:

$EPI_{it} = \beta_0 + \beta_1 NGC_{it} + \beta_2 FDI_{it} + \beta_3 CRED_{it} + \beta_4 TROPEN_{it} + \beta_5 GDPPC_{it} + \mu t + \varepsilon 1_{it}$ (9)

$CPC_{it} = \beta_0 + \beta_1 NGC_{it} + \beta_2 FDI_{it} + \beta_3 CRED_{it} + \beta_4 TROPEN_{it} + \beta_5 POPL_{it} + B_6 GDPPC_{it} + \mu t + \varepsilon 1_{it}$ (10)

where: Where: EPI = Environmental performance index; CPC = CO2 emission per capita
NGC = Natural gas consumption; FDI = Foreign Direct Investment; CRED = Credit to the private sector; TROPEN = Trade openness; POPL = Population; GDPPC = GDP per capita; β_0 =Regression intercept, $\beta_1 - \beta_6$ = Parameter estimates of the explanatory variables (including the main and control) in each model.$_t$ = time subscript, μ_t = cross-section or firm-specific error component; $\varepsilon 1_{it}$ = combined time series and cross-section error component

The above dataset was sourced fromthe World Development Indicators of World Bank, Africa Energy Portal (AEP), and International Energy Agency (IEA) for the period 1990 – 2022. In analyzing the data, the Panel Least Squares method was used to estimate the parameters of the regression model. The adoption of this technique was based on the premise that the Panel Least Square is assumed to be the Best Linear Unbiased Estimator. It also has minimum variance.

IV. RESULTS

The plotted line graph in figure 1 shows the trend in Environmental Performance Index among the selected countries namely Algeria, Angola, Egypt, Ghana, Libya, and Nigeria. The line graph depicting the environmental performance index in each country from 1990 to 2022. During the bulk of the sample period, Egypt had the highest environmental performance index (EPI), except for a few years when Algeria had a higher EPI than Egypt. Furthermore, Libya consistently had the lowest environmental performance index for most of the study period.

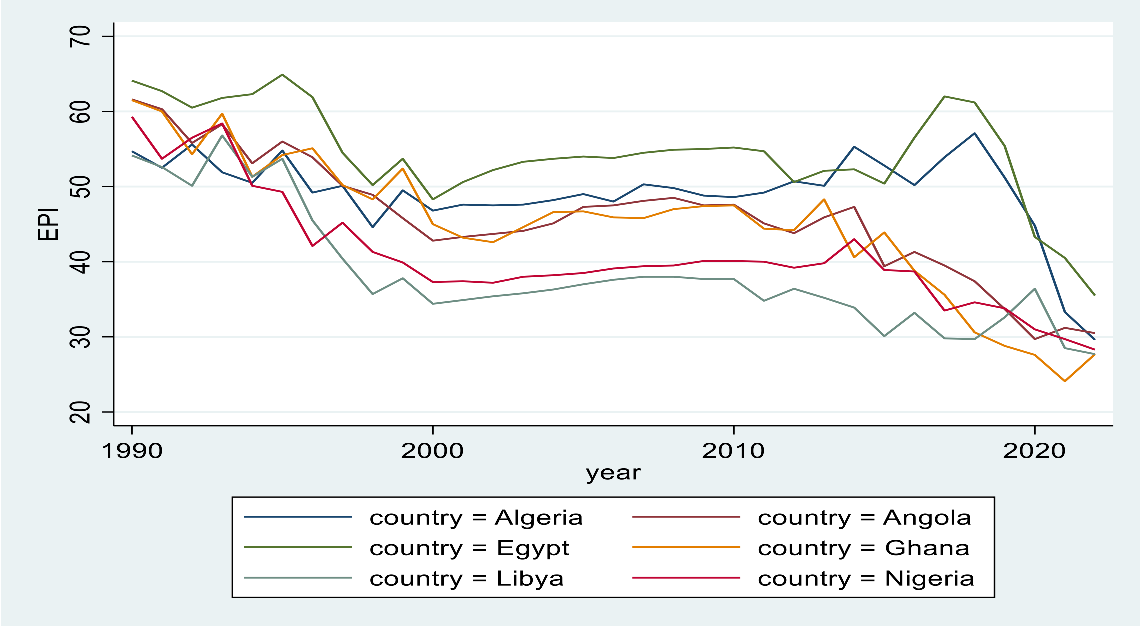

Figure1: Line graph showing trend in Environmental Performance Index (EPI) among the Selected African Countries
Source: Author's Plot, 2024.

Figure 2 reveals that Egypt has a higher per capita carbon dioxide (CO_2) emission compared to the other African countries included in this study. Algeria is the country with the second greatest volume of CO_2 emissions per capita, right after Egypt. Moreover, during the study period, Ghana consistently maintained the lowest carbon dioxide emissions per person.

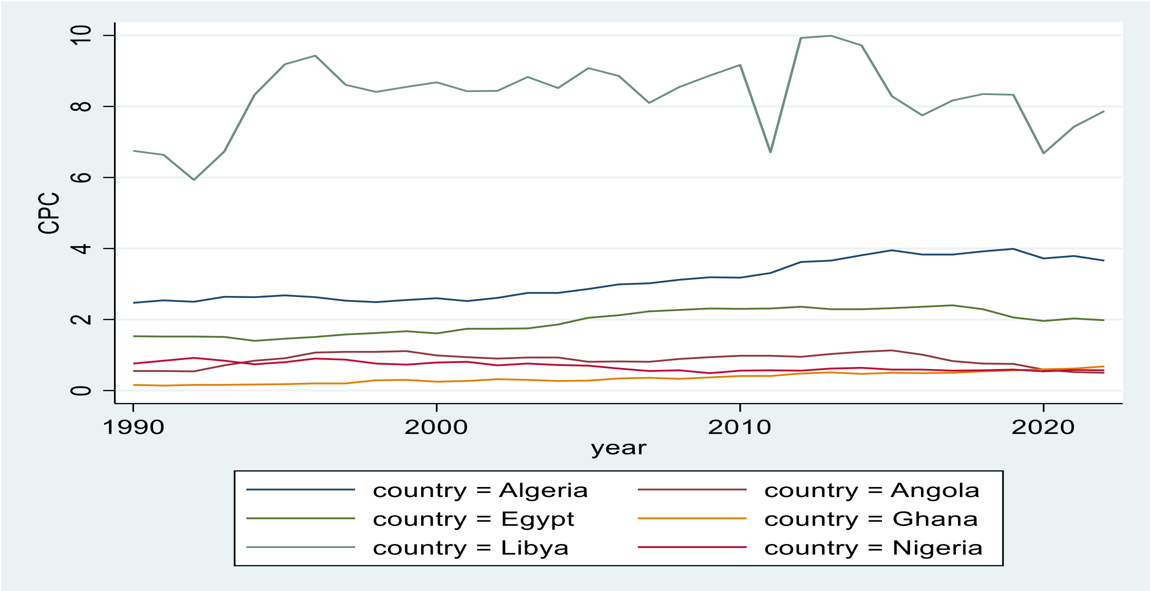

Figure 2: Line graph showing trend in CO2 emission per capita(CPC)among the Selected AfricanCountries
Source: Author's Plot, 2024.

As evidenced in Figure 3, Algeria had the highest consumption of natural gas, which also had constant growth from 1990 to 2022. Ghana had the lowest consumption of natural gas over the specified period. Moreover, the line graphs demonstrate that Angola had a higher degree of fluctuation in natural gas consumption over the given period.

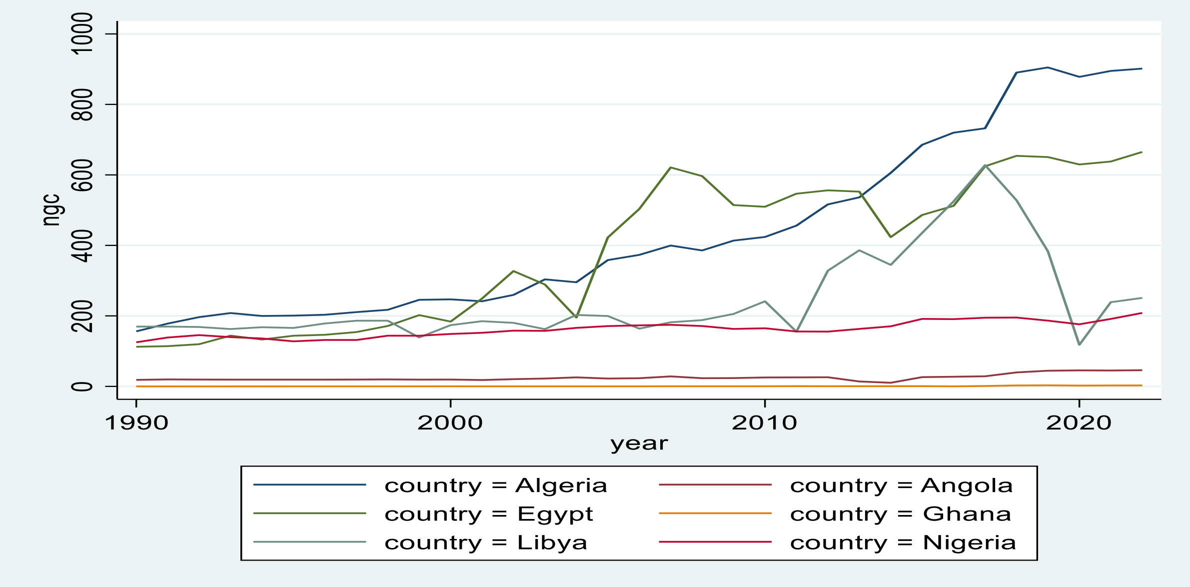

Figure 3: Line graph showing trend in Natural Gas Consumption (NGC) among the selected African countries.
Source: Author's Plot, 2024.

Table 1 presents a concise overview of the dataset, based on the number of observations (N = 198), the number of cross sections (i.e., countries) (n = 6), and the time period covered (T = 33). This table displays the summary statistics including the means, standard deviations (overall, between nations, and within countries), minimum and maximum values, skewness, and kurtosis. Statistical characterization of the variables is essential for examining the distribution and variability of the variables under study. This is done to avoid the potential issues that may arise when working with time series and cross-section data. All the variables display considerable variation both between and within countries. This suggests that the use of panel estimation techniques, which allows the identification of the various parameters of interest, is reasonable. For example, while the mean statistic is computed to be 45.65, the overall, between and within standard deviation statistics for environmental performance index are 9.14, 5.73, and 7.48 respectively. This implies that, on average, the selected countries performed below average with respect to environmental performance, and that although there is variation in their performance index, it cannot be said to be a huge one. Moreover, the skewness and kurtosis statistics are -0.14 and 2.25. This impliesa left-skewed (since the skewness statistic is negative) and platykurtic (fewer and less extreme outliers) (since the kurtosis statistic less than 3) distribution. More outliers were evident in CO2 emission per capita as again fewer outliers in environmental performance index (EPI).

Table 1. The results of summary statistics for selected variables (N =198; *n* = 6 countries; *T* = 33)

Variables	Mean	Overall Std. Dev	Between Std. Dev.	Within Std. Dev.	Min	Max	Skewness	Kurtosis
EPI	45.65	9.14	5.73	7.48	24.1	64.9	-0.14	2.25
CPC	2.54	2.78	2.98	0.49	0.14	9.99	1.44	3.72
NGC	209.74	218.15	181.65	141.25	0.04	904.94	1.32	4.18
GDPPC	3.46	2.93	3.37	0.92	0.85	13.73	2.15	6.77
TROPEN	61.24	24.70	20.19	17.38	16.35	152.55	0.99	3.97
CRED	18.41	12.27	9.21	8.37	3.66	56.14	1.38	4.47
FDI	2.17	4.72	1.35	4.55	-10.72	40.17	3.60	26.94
POPL	52.74	52.22	53.90	17.13	4.24	218.54	1.39	4.11

Source: Author's computation, 2024.

The results of the Im, Pesaran and Shin (IPS) panel unit root test conducted on each of the variables are presented in Table 2. The test was conducted under the constant and constant and trend random walk conditions. The decision rule is based on the comparison of the test statistic with the 5% critical value under each of the random walk assumptions. The null hypothesis is rejected when the test statistic is greater than the 5% critical value under both of the random walk assumptions. The results presented showed that while *cred*, and *fdi* were all stationary at level; *lnepi*, *lncpc*, *lnngc*, *lngdppc*, *tropen*, and *lnpopl* only became stationary after first differencing. For example, while the absolute value of the test statistic (i.e., 2.15 and 2.89) is greater than the 5% critical value under both of the random walk assumptions (i.e., 2.07 and 2.68). The test conducted on *lnepi* and *lncpc*under panel B (i.e., test at first difference). The stationarity of the panel data variables validates their incorporation into the model for the purpose of estimating the relationship between the dependent and independent variables.

Table 2:The results of the Panel Unit Root Tests

Variables		**Levels**						
		Constant			**Constant and Trend**			**Decision**
		Test Statistic	5% Critical value		Test Statistic	5% Critical value		
Lnepi		-2.35*	-2.07		-2.40	-2.68		Non-Stationary
Lncpc		-0.92	-2.07		-2.11	-2.68		Non-Stationary
Lnngc		2.00	-2.07		-3.04*	-2.68		Non-Stationary
Lngdppc		-1.64	-2.07		-2.04	-2.68		Non-Stationary
Tropen		-2.39*	-2.07		-2.46	-2.68		Non-Stationary
Cred		-2.38*	-2.07		-3.13*	-2.68		Stationary
Fdi		-2.73*	-2.07		-3.25*	-2.68		Stationary
Lnpopl		0.50	-2.07		1.50	-2.68		Non-Stationary
Variables		**First Difference**						
		Constant			**Constant and Trend**			**Decision**
		Test Statistic	5% Critical value		Test Statistic	5% Critical value		
D.lnepi		-6.12*	-2.07		-6.14*	-2.68		Stationary
D.lncpc		-5.32*	-2.07		-5.54*	-2.68		Stationary
D.lnngc		-6.86*	-2.07		-6.78*	-2.68		Stationary
D.lngdppc		-6.24*	-2.07		-6.15*	-2.68		Stationary
D.tropen		-5.56*	-2.07		-5.61*	-2.68		Stationary
D.lnpopl		2.91*	-2.07		-2.97*	-2.68		Stationary

Panel data cointegration test was conducted for the two (2) specified models to determine the presence or absence of a long run relationship between the variables in each of the models of interest in this study. The results of the Pedroni panel cointegration test are presented in Tables 3, models 1&2 are multiple panel regression models specified to examine the impact of natural gas consumption on environmental degradation-with environmental performance index and CO2 emission per capita as dependent variables respectively.

The panel cointegration test result presented in Table 3 shows that we cannot fail to reject the null hypothesis of no cointegration between the variables in each of the models tested. The results show that at no point did all the test statistics for the respective models prove to be statistically significant. Though some of the test statistics proved significant for the carbon emission per capita model, it was not sufficient to decide that a cointegrating relationship exists between the variables in each of the models. Hence, the econometric technique adopted for estimating the models ignores the estimation of an error correction term.

Table 3: The results of Pedroni (2004) test of cointegration for models estimated

S/N	**Models**	**Modified Phillips-Perron t** Stat. [p-value]	**Phillips-Perron t** Stat. [p-value]	**Augmented Dickey Fuller t** Stat. [p-value]	**Comment**
1	EPI Model	0.56[0.29]	-1.55[0.06]	0.45[0.32]	No Cointegration
2	CPCModel	1.23[0.000]	-7.60*[0.000]	0.80[0.21]	No Cointegration
Note 1: * signifies significance at 5% levels of significant errors respectively. Note 2: **Source:** Authors' computation, 2024.					

Table 4 displays the outcomes of the panel regression analysis on how consumption of natural gas affects the environment using the environmental performance index and CO2 emission per capita as dependent variables. The estimated model results for the environmental performance index as a dependent variable (model I) are shown in panel A of Table 4 while the results for CO2 emission per capita as a dependent variable (model II) are displayed in panel B of Table 4. The Hausman test indicates that fixed effect models are the best suitable for interpretation due to the statistically significant test statistics (92.88 and 65.22) at the 1% significance level (p-value < 0.01). Hence, going forward, the interpretation of the result will be solely based on the fixed effect models. Firstly, the result of the fixed effect model estimated to examine the impact of natural gas consumption on the environmental performance index shows that the coefficient (i.e., -0.1251) of the natural log of natural gas consumption (*lnngc*) appeared with a negative sign. This implies that natural gas oil consumption had a negative impact on the environmental performance index in all the selected countries. The p-value (i.e., 0.000) shows that the coefficient of natural gas consumption is statistically significant at the 1% level of significant error. Moreover, the coefficients (i.e., 0.1265, -0.0016, 0.0007, and -0.1161) of the control variables appeared with both positive and negative signs. This implies that while foreign direct investment and trade openness have a positive impact on the environmental performance index, credit to the private sector and per capita income have a negative impact on the EPI. However, only foreign direct investment proved to be statistically significant at 5% level of significant error. While the within R-squared and between R-squared statistics were computed as 0.4577 and 0.0002, respectively, the overall R-squared is computed as 0.0060. This suggests that the model, on average, explains 45.77% of the variation within the panel variables, 0.02% of the variation between the panel variables, and 0.60% of the variation in the entire panel data. The computed F-statistic (i.e., 24.64) and its p-value (i.e., 0.000) imply that the dependent variable is significantly explained by the independent variables in the model. Thus, the entire model is statistically significant.

Independent variables	Panel A: Model I (Dependent variable = Environmental performance Index)				
	Fixed Effect		**Random Effect**		**Hausman Test**
	Coefficient	P-value	Coefficient	P-value	chi2 (p-value)
Lnngc	-0.1251***	0.000	0.0340***	0.000	92.88***
Fdi	0.1265***	0.013	0.0051	0.353	(0.000)
Cred	-0.0016	0.166	0.0047***	0.000	
Tropen	0.0007	0.274	0.0024**	0.013	
Lngdppc	-0.1161*	0.053	-0.2149***	0.000	
const.	4.3978***	0.000	3.6475***	0.000	
R^2_W	0.4577	-	0.0123	-	
R^2_B	0.0002	-	0.6553	-	
R^2_O	0.0060	-	0.2921	-	
F-stat.	24.64***	0.000	-	-	
Wald	-	-	62.31***	0.000	
Independent variables	Panel B: Model II (Dependent variable = CO2 emission per capita)				
	Fixed Effect		**Random Effect**		**Hausman Test**
	Coefficient	P-value	Coefficient	P-value	chi2 (p-value)
Lnngc	0.3307***	0.000	0.3398***	0.000	65.22***
Fdi	0.0173***	0.000	0.0362***	0.000	(0.000)
Cred	0.0009	0.543	0.0068***	0.000	
Tropen	0.0008	0.332	0.0015	0.154	
Lngdppc	0.4263***	0.000	0.1809***	0.005	
Lnpopl	-0.6773**	0.000	-0.6206***	0.000	
const.	0.9214**	0.021	-0.7455***	0.000	
R^2_W	0.6822	-	0.6163	-	
R^2_B	0.9567	-	0.9823	-	

R^2_O	0.9574	-	0.9715	-
F-stat.	51.88***	0.000	-	-
Wald	-	-	5111.88***	0.000

Note 1: *, **, and *** signifies significance at 10%, 5%, and 1% levels respectively. **Note 2:** R^2_W = R-squared within; R^2_B = R-squared between; and R^2_O = R-squared overall.
Source: Author's computation, 2024.

Second, the fixed effect model estimate, which examined the impact of natural gas oil consumption on CO2 emission per capita, revealed a positive sign in the coefficient (i.e., 0.3307) of the natural log of natural gas oil consumption (*lnngc*). This implies that natural gas consumption had a positive impact on CO2 emissions per capita in all the selected countries. Also, the p-value (i.e., 0.000) shows that the coefficient of natural gas consumption is statistically significant at 1% level of significant error. Moreover, the coefficients (i.e., 0.0173, 0.0009, 0.0008, and 0.4263) of the control variables appeared with positive sign. This implies that foreign direct investment, credit to the private sector, trade openness, and per capital income impact positively on CO2 emissions per capita. However, only foreign direct investment and per capita income proved to be statistically significant. While the within R-squared and between R-squared statistics were computed as 0.6822 and 0.9567, respectively, the overall R-squared is computed as 0.9574. This suggests that the model, on average, explains 68.22% of the variation within the panel variables, 95.67% of the variation between the panel variables, and 95.74% of the variation in the entire panel data. The computed F-statistic (i.e., 51.88) and its p-value (i.e., 0.000) imply that the dependent variable is significantly explained by the independent variables in the model. Thus, the entire model is statistically significant.

Table 4:The results of models estimated to examine the impact of natural gas consumption on environmental degradation.

The post-estimation diagnostic test results for the two models estimated to examine the impact of natural gas consumption on environmental degradation are presented in panels A and B of Table 5. While the post-estimation diagnostics test results of the model with environmental performance index as a dependent variable (i.e., model I) are presented in panel A of Table 5 the post-estimation diagnostics test results of the estimated model with CO2 emission per capita as a dependent variable (i.e., model II) are presented in panel B of Table 5. From the results presented in Table 5 we observe that we failed to reject the null hypotheses in all the tests conducted. This is so because while the p-values of the test statistics for heteroscedasticity, autocorrelation, Ramsey RESET omitted variables, and normality test were all greater than 0.05, the stability test statistics (i.e., 0.7162 and 0.5301) were less than the 5% critical value (i.e., 0.9479).

Table 5: The results of post-estimation diagnostic tests for the models estimated to examine the impact of natural gas consumption on environmental degradation.

Panel A: Model I (Dependent variable = Environmental performance Index)				
Tests	**Test Statistic**	**Test of significance**		**Comment**
		P-value	5% critical value	
Heteroscedasticity	0.52	0.4704	-	Fail to reject null hypothesis
Autocorrelation	3.722	0.0556	-	Fail to reject null hypothesis
Stability (Recursive)	0.7162	-	0.9479	Fail to reject null hypothesis
Omitted variables	1.30	0.2774	-	Fail to reject null hypothesis
Normality	0.1449	0.9301	-	Fail to reject null hypothesis
Panel B: Model II (Dependent variable = CO2 emission per capita)				
Tests	**Test Statistic**	**Test of significance**		**Comment**
		P-value	5% critical value	
Heteroscedasticity	2.68	0.0908	-	Fail to reject null hypothesis
Autocorrelation	2.483	0.1171	-	Fail to reject null hypothesis
Stability (Recursive)	0.5301	-	0.9479	Fail to reject null hypothesis
Omitted variables	1.94	0.1247	-	Fail to reject null hypothesis
Normality	3.505	0.1733	-	Fail to reject null hypothesis

Note 1: * signifies significance at 5% levels of significant errors respectively.
Source: Authors' computation, 2024.

Also, the recursive CUSUM plot presented in figures 4(a) and 4(b) shows that the plots fell within the 5% critical area. Hence, we conclude that the two models passed all the post-estimation tests.

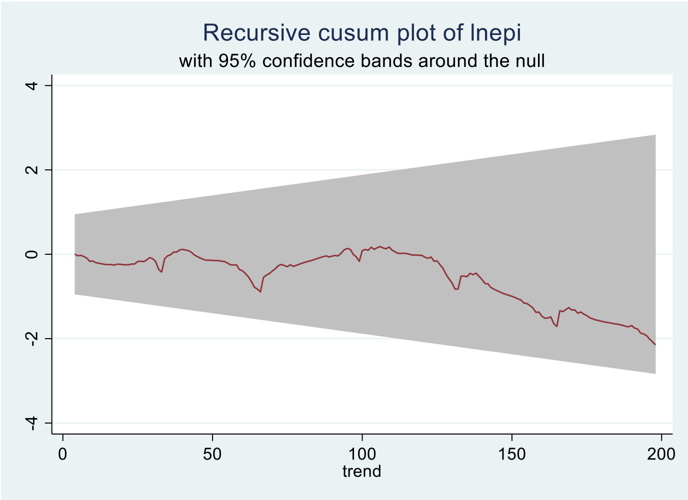

Figure 4(a): Recursive cumulative plot of EPI model estimated to examine the impact of NGC
Source: Author's computation, 2024.

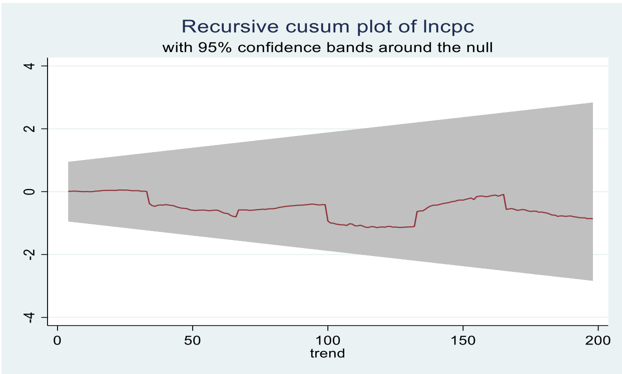

Figure 4(b): Recursive cumulative plot of EPI model estimated to examine the impact of NGC
Source: Author's computation, 2024.

V. FINDINGS

The study investigated the impact of natural gas energy consumption on environmental sustainability in selected African countries. Significant findings have emerged from the data analysed and results arrived at. The study found that the consumption of natural gas contributed to environmental degradation by reducing the environmental performance index and increasing the CO2 emission per capita. The finding on the effect of natural gas consumption on the environment conforms with the study by Oladipupo et al. (2022), Khan and Rehan (2020), Muhammad et al. (2020), Nkengfack and Fotio (2019), Mallesh and Asharani (2019), Hanif (2018), and Boontome et al. (2017) who found that that non-renewable energy (like petroleum oil and natural gas) consumption contributes environmental degradation. Also, the finding of this study disagrees with the studies by Isik, Ongan and Özdemir (2019) and Nwatu and Ezenwa (2020) who found that fossil fuel energy consumption reduces CO2 emission. FDI was found to significantly improve environmental performance while trade openness also improves the performance of the environment but marginally. This result is not in tandem with earlier study by Abdukarim (2003) which found trade to be environmentally unfriendly. GDP per capita and credit to the private sector were found to retard environmental performance index in Africa.

The study furtherfound that FDI and GDP per capita contributed to environmental degradation significant while credit to the private sector and trade openness marginally destroyed the environment in terms of CO2 emission per capita. Only population growth rate was found to significantly reduced CO2 emission in Africa. The finding from the population growth variable may not be far from the low consumption of natural gas and energy in Africa as earlier pointed out in this study.

VI. CONCLUDING REMARKS AND RECOMMENDATIONS

This effect of natural gas on environmental sustainability among selected African countries was examined in this study. The six selected African countrieswere: Angola, Algeria, Egypt Ghana, Libya, and

Nigeria and the study cover the period 1990-2022. To achieve the purpose of this studynatural gas consumption was analysed along with foreign direct investment, credit to the private sector, population growth rate, GDP per capita and trade openness to determine their impact on environmental performance index and carbon emission per capita (proxy for environmental sustainability) using panel analysis. Based on the analysis of the data using panel fixed effect regression econometric technique, some key empirical findings were made. Egypt had the highest environmental performance index (EPI) and per capita carbon dioxide (CO2) emission. Algeria consumed more of natural gas than any of the countries selected for the study. Direct relationship between the natural gas consumption and environmental performance index (EPI) was visualised in Algeria, Egypt and Nigeria. Natural gas consumption had a negative and significant impact on the environmental performance index while natural gas consumption had a positive and significant impact on CO2 emission per capita.FDI was found to significantly improve environmental performance while trade openness also improves the performance of the environment but marginally. GDP per capita and credit to the private sector were found to retard environmental performance index in Africa. The study further found that FDI and GDP per capita contributed to environmental degradation significant while credit to the private sector and trade openness marginally destroyed the environment in terms of CO2 emission per capita. Only population growth rate was found to significantly reduced CO2 emission in Africa.

Consequent upon the findings, the study concludes that a variation exists in the relative impact of natural gas consumption on environmental sustainability among the selected African countries. Moreover, this study concluded that natural gas consumption will more likely be consistent in improving environmental quality and sustainability in Africa. Based on the findings and conclusion, the study recommends: increase investment in natural gas production, consumption and renewable energy by African countries especially renewable energy in order to improve and sustain the environment.

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