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Natural Gas Consumption and Economic Growth: Empirical Evidence from Selected African Countries

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study investigated the impact of natural gas consumption by the industrial sector, residential/households and transport sector on economic growth of selected countries in Africa (Algeria, Egypt, Equatorial Guinea, Ghana, Nigeria and Tunisia) over the period 1990 – 2021. In order to achieve this objective, data on growth rate of gross domestic product (RGDP), total natural gas consumption, industrial gas consumption, residential gas consumption and natural gas consumed by the transport sector of the selected countries were sourced from the World Bank Development Indicators and International Energy Agency (IEA) and analyzed using panel Autoregressive Distributed lagged (ARDL) method. The results of our analysis show that: Total natural gas consumed has negative and significant impact on economic growth in the long run but positive and significant effect on economic growth of the selected countries in the short run. Industrial gas consumption has positive and significant impact on economic growth of the selected countries both in the short and long run. Residential gas consumption has positive and significant impact on economic growth in the long run but negative and insignificant effect on economic growth in the short run. Natural gas consumed by the transport sector has positive but insignificant effect on economic growth of the selected countries over the period under study. The impact of natural

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gas consumption on economic growth for all the countries under study does not vary. That a long run relationship exists between natural gas consumption and economic growth among the countries been investigated. Based on these findings, the study recommended that governments of African countries under investigation should encourage natural gas consumption in the industrial, transport and households by building gas infrastructure and investment in the oil and gas sector in order to stimulate economic in the sub region.

Keywords: Economic growth; natural gas utilisation; industrial sector; transport sector; household.

1. INTRODUCTION

Prior to the 1980s, it was often thought that possessing a surplus of natural resources had a favourable influence on economic growth at a time when the global economy had not yet fully expanded. From this perspective, the copiousness of natural resources was seen as a good mechanism for promoting economic growth. The proceeds derived from natural resources are allocated to invest in many sectors of the economy, so supporting the transformation of nations from less developed to more developed ones, as shown by the United States, United Kingdom, and Australia. Furthermore, the act of amassing foreign reserves may be seen as a beneficial tactic to lessen the unfavourable result of both internal and foreign disturbances, likewise to interfere in the global market. However, since the 1980s, the notion that possessing a surplus of natural resources is advantageous and results in economic growth has been questioned because to the inability of several resource-rich nations to attain consistent economic growth and development. Excess of natural resources might lead to unfavourable economic consequences. Socioeconomic phenomena i.e. the resource curse, Dutch disease, revenue volatility, irrational and emotional behaviour of the elite promoting poor resource management, and rent-seeking political actors exploiting natural resource wealth for personal gain all contribute to retarding economic growth, high inflation rate, low savings, high unemployment, instability in export earnings, corruption, poverty, and a low level of human development. Akokaike, Adenikinju, Ekpe, Eleri, Ajulo, and Gini [1] noted that despite natural gas being acknowledged as a clean, cost-effective, and environmentally friendly energy source with larger proven reserves than oil, the oil industry continues to receive favourable treatment, unfavourably impacting the real sector. In general, natural gas is an essential component of the energy mix, providing several potential benefits. Unfortunately, the utilisation of natural gas in sub-Saharan Africa is now at a significantly diminished level. Only a tiny proportion of the available gas reserves is utilised for electricity generation. The minimum use of petrol is seen in crucial sectors of the economy, i.e. transportation, residential, and commercial sectors. Sub-Saharan African nations often suffer from inadequate infrastructure and insufficient investment in natural gas projects. Many factors adversely affect the domestic use of natural gas, resulting in economic stagnation in many nations. The ongoing practice of gas flaring in West Africa is a significant threat to the region's economic progress and is a major factor contributing to the poor utilisation of natural gas. Moreover, the pollutants generated by gas flaring provide significant hazards to both humans and the environment. These concerns arise from the presence of greenhouse gases in producing regions, acid rain, depletion of the ozone layer, decreased agricultural output, and health complications. This obstacle also results in a lack of electrical provisions and insufficient resources for the industrial and manufacturing sector. Consequently, sub-Saharan Africa has been unable to properly use its natural gas deposits to successfully enhance and expedite economic growth. Africa still faces the challenge of insufficient energy supply and a lack of natural gas resources for industrial purposes. This scenario is dangerous and frightening for the continent since it is not using its natural gas resources as part of its energy portfolio.

The link between natural gas consumption and economic growth has received increasing attention throughout time, leading to several empirical studies investigating this correlation (Udo, Idamoyibo, Victor, Akpan, and Victor [2], Ishioro [3], Ekeocha, Penzin, and Ogbuabor [4], Maji, Chindo, and Rahim [5], Nkengfack and Fotio [6], and Enu and Havi [7]. After examining these previous research works on the nexus between natural gas consumption and economic growth, it was found that the majority of these studies concentrated on the influence of electricity consumption, energy consumption, or

oil consumption on economic growth with few examining the effect of natural gas on economic growth at the regional level. This implies that there is a dearth of comprehensive study that has included sub-Saharan African states. In addition, a limited number of research employed panel data, and none of them extended their investigation beyond the year 2021. The study intends to address these concerns as possible limits. Hence the objective of the study is to examine the relationship between the utilisation of natural gas and the growth of the economy in certain African nations, including Algeria, Egypt, Equatorial Guinea, Nigeria, Ghana, and Tunisia. The research will be performed applying panel data spanning from 1990 to 2021. The research progresses by first performing a comprehensive examination of relevant literature, and then applying a particular technique to examine the data gathered for the study. Next, the outcomes and remarks are provided, which are then followed by concluding statements and recommendations.

2. LITERATURE REVIEW

According to the Biophysical theory by Kardashev, energy resource such as natural gas is essential for productivity and economic growth in an economy. Human labour, energy, and material resources are the three pillars upon which the world economy rests. In order to encourage economic growth, provide the way for industrial expansion, and generate employment opportunities, energy costs are imperative. When it comes to running a business efficiently, energy is king. More than just powering manufacturing, energy's capacity to create and improve value is what drives economic expansion. Experts in ecological economics and the natural sciences place a high value on the economic advantages of having widely accessible and readily available energy for manufacturing. Energy is the one variable that dictates output, in line with those who advocate for the biophysical theory of economic growth (Stern, 1999). Conversely, traditional economists purposefully disregarded energy as a production element because of the constraints placed on economic processes by land, particularly in agriculture. Recognising land as a production element in agriculture is an indirect way energy is integrated into the economy [8]. The neutrality thesis, which maintains that energy and economic growth are unrelated, lends credence to this. Energy saving initiatives could not significantly affect GDP growth, in line with Aghion and Howitt [9]. Environmentalists and conventional economists agree that fossil fuels and other forms of energy are intermediate inputs that boost industrial value and contribute to economic growth. Energy, labour, and land are seen as crucial components of production, conversely. Considering the vital role that energy plays in manufacturing, it is imperative to look at how natural gas, a major energy source, has affected Nigeria's GDP growth level.

The link between natural gas consumption and national income in different nations has been the subject of empirical research. Research conducted by Alam, Paramati, Shahbaz, and Bhattacharya [10] investigated the link between emerging nations' usage of natural gas and the development of production. In line with the result, the utilisation of natural gas plays a crucial role in deciding the rate of economic growth for the nations that made up the sample. Research has shown that increasing the usage of natural gas has a favourable impact on the growth of output. Natural gas use is strongly and statistically significantly associated with economic growth, in line with new study by Akokaike, Adenikinju, Ekpe, Eleri, Ajulo, and Gini [1]. A combination of fixed effects and least squares dummy factors revealed this association. In line with Foye and Benjamin [11], there is a strong and persistent correlation between real GDP and natural gas consumption. Utilisation of natural gas was also favourably associated with short run economic success, in line with the research. The 2019 study by Fadiran, Adebusuyi, and Fadiran looked at twelve major European nations in the gas market and how their use of natural gas correlated with their economic growth. The use of natural gas was shown to be significantly associated with long run economic growth. An increase in natural gas use may support Nigeria's long run economic advancement, in line with study by Mukhtar and Abubakar [12].

The natural gas sector, exports, labour, and economic growth are all favourably related, as Abdul and Liang [13] found to be the case. Natural gas consumption is favourably correlated with short run economic growth in Mozambique, in line with the research.

A study was carried out by Nwabueze, Ogbonna, and Nwaozuzu [14] in order to examine the nexus between crude oil prices, per capita GDP in Nigeria, FDI, natural gas usage, and natural gas prices. For this study, they used the VECM, or Vector Error Correction model. While the price

of natural gas has no effect on consumption, the VECM estimate, Granger causality test, and Variance decomposition tests all show that there is a strong favourable nexus between natural gas consumption and economic advancement (as measured by per capita GDP) in Nigeria. Therefore, Nigeria is anticipated to see an increase in the utilisation of natural gas as a result of economic policies that promote the production of products and the delivery of services while changes in the price of crude oil had a much larger impact on natural gas use than FDI did in the end. Based on these findings, it seems that fluctuations in the price of crude oil throughout the world have a more significant impact on Nigeria's FDI influx than changes in the nation's petrol consumption, everything else being equal.

From 1999Q1 to 2016Q4, Ekeocha, Penzin, and Ogbuabor [4] utilised a variety of model assumptions to investigate the connection between energy consumption and economic growth in Nigeria. The research utilised an ARDL-error correction model (ECM) specification that presupposes a linear connection instead of a nonlinear one, and a nonlinear (or asymmetric) ARDL model. The study's results show that energy use does not significantly impact on Nigeria's GDP growth. This indicates that there is still a need for substantial efforts to guarantee that energy plays a more major part in the nation's economy. A one-way link between energy use and GDP growth was found applying the granger causality tests. In line with these upshots, if Nigeria's energy supply is improved and made more reliable, the nation might achieve constant and considerable economic growth. Accordingly, the study's findings should act as a strong reminder to the Nigerian government and other policymakers in Sub-Saharan African nations with comparable economies that they must act quickly to address the energy problems their economies are experiencing.

In their study, Mukhtar and Abubakar [12] utilised a nonlinear autoregressive distributed lag (NARDL) model to look at how natural gas affected economic advancement (growth) in Nigeria. A comprehensive analysis of natural gas's favourable and unfavourable impacts was carried out by the experts. In line with the result, there are a range of potential favourable and unfavourable effects of natural gas use on GDP growth in the long run. Based on this result, asymmetric repercussions in the near future are not yet supported by any research. Nevertheless, when looking at the big picture over a long period of time, the beneficial influence grows by 0.15 percent for every one percent rise, whereas the unfavourable impact is negligible. In line with the results, increasing the use of natural gas may lead to long run economic expansion. In addition, efforts to save energy and improve energy efficiency do not slow down development, which means that economic growth will not be affected. Among the energy efficiency measures recommended by the research for the Nigerian government are the installation of water booster heaters and the widespread use of light-emitting diode (LED) or compact fluorescent lamp (CFL) bulbs, which use far less power than incandescent bulbs. Adopting this approach makes it possible to reduce energy costs, combat climate change, and achieve long run economic growth.

Research conducted by Okwanya and Abah [15] studied the link between energy consumption and poverty reduction in a sample of 12 African nations from 1981 to 2014. Applying the Fully Modified Ordinary Least Square (FMOLS) approach, the research demonstrated that in the chosen African nations, there is a consistent inverse link between energy use and poverty level. The significance of electricity in reducing poverty is shown by this. Capital stock and political stability are two characteristics that have a major impact on poverty reduction, in line with the study. This suggests that these traits significantly contribute to alleviating poverty. In addition, the granger causality test showed that, in the short run, energy consumption causes poverty. The results show that a decrease in the poverty rate is associated with higher energy use. In line with the research, in order to optimise the benefits of energy consumption in reducing poverty, the governments of the chosen nations should invest in infrastructural improvements and maintain political stability.

To find out what factors affect the frequency of natural gas flaring in Nigeria, Reuben [16] conducted empirical research. In order to determine what factors, influence Nigeria's natural gas flaring, this research utilised the ARDL bounds test. Data from the years 1984 to 2013 were utilised to conduct the study. In line with research, there are a lot of imperative factors that affect how often Nigerians flare their natural gas. Flaring penalties, crude oil production levels, natural gas pricing, monetization of natural gas, and infrastructural

gaps are some of the factors impacting the issue. The production of crude oil is the primary cause of the growth in gas flaring, whereas the commercialization of natural gas is the most effective way to reduce gas flaring. Researchers found that improving natural gas flaring rules had the best chance of reducing flaring over the long run, which would help Nigeria reach the World Bank's 2030 goal of eliminating regular flaring.

Oghenegare [17] looked at how fuel usage and Nigeria's economic growth rate were related. Gas Flared (GF), Gas Utilised (GU), and Gross Domestic Product (GDP) are the independent variables in an econometric model that was developed applying the Cobb-Douglas production function. Applying yearly time series data from 2004–2014, the model was tested applying OLS regression. In line with the result, there is a favourable relationship between fuel use and GDP. In order to make good use of Nigeria's natural gas reserves inside the nation, the research suggested that the Federal Government of Nigeria establish suitable legislation and fully implement the Nigeria Gas Master Plan.

Ahmed [18] conducted research to examine the link between household fuel use and the Nigerian economy. To evaluate the dynamic link, a Granger causality test was utilised. Based on the result, it can be concluded that domestic fuel use is not causally related to economic advancement (growth). There seems to be no relationship between GDP growth and fuel use, in line with the findings. Improving natural gas role in the nation's energy mix requires targeted policies and investments in the gas industry, which in turn boosts the economy. It follows that economic advancement does not, on its own, lead to a rise in petrol consumption, as the nation's fuel consumption does not change in response to economic growth. The main reason for this is because the nation's economy is highly reliant on crude oil. So, it is not possible to use the present gasoline consumption pattern to accurately forecast the ebb and flow of the Nigerian economy. Based on the results, the gas sector may greatly boost economic output with more investment and better infrastructure. The economy as a whole would become more reliant on the gas industry as a result.

Research by Ouedraogo [19] looked at the link between ECOWAS member states' energy use and GDP development. Applying data collected from fifteen (15) ECOWAS member nations between 1980 and 2008, the researchers looked at the nexus between energy use and GDP growth rate. Applying panel cointegration and granger causality, the research found that energy consumption is favourably related with GDP and that the two variables move in tandem over the long run. A one-way causation was also discovered by the researchers; in the long run, energy consumption leads to GDP, but in the short run, the inverse is true.

From 1971 to 2006, Noor and Siddiqi [20] studied the relationship between Nigeria's per capita energy consumption and GDP applying cointegration and OLS techniques. The cointegration result indicates that the model variables have a strong and persistent link over a long period of time. There is a unfavourable relationship between energy consumption per capita and GDP per capita, in line with the long run estimated equation. Furthermore, the causality test reveals that, in the short run, energy consumption is directly related to gross domestic product.

The result of natural gas use on the GDP growth of several sub-Saharan African nations from 1998 to 2017 was studied in a study by Foye and Benjamin [11]. Emirmahmutoglu and Kose demonstrated that panels with mixed heterogeneity may be evaluated applying the Toda and Yamamoto method of lag augmented vector autoregression. Furthermore, data analysis makes use of eclectic, ever-changing methodologies. In line with the results, there is a strong and persistent relationship between actual GDP and natural gas use. Utilisation of natural gas was also favourably associated with short run economic success, in line with the research. The results also provide credence to the cautious hypothesis with regard to the chosen sub-Saharan African nations. Consequently, it is reasonable for the chosen sub-Saharan African nations to develop and advocate for environmentally friendly and economically viable energy and environmental programmes that will increase natural gas use.

Researchers Itoua, Manguet, and Moufanda-Mouanda [21] studied the link between the Republic of Congo's GDP growth from 2006 to 2019 and gas production, consumption, and flaring. The unit root test shows that most variables are level stationary, which means they are zero-order integrated. However, when differentiated once, the labour input variable shows stationarity, indicating that it is integrated

of order one. There is a stable long-term link between all-time series, and the Johansen cointegration test verifies that. Additionally, the Granger-causality test was conducted in the study. The result shows that the only factors directly influencing economic growth are gas production and gas utilisation. Gas use has a substantial favourable outcome on GDP, but gas production has a substantial unfavourable effect, in line with the OLS regressions.

An investigation of the nexus and cause-and-effect connection among energy use, GDP growth, and carbon emissions was undertaken by Nkengfack and Fotio [6]. From 1971–2015, they analysed energy use in South Africa, Algeria, and Egypt using both aggregate and specific metrics. The research found that economic growth and collective energy consumption significantly reduced CO2 emissions in those nations over the short run and long run, applying the ARDL limits testing method. Carbon emissions in Algeria, Egypt, and South Africa are mostly caused by individual use of oil, electricity, and coal, respectively. Additionally, the Toda-Yamamoto test for causation has shown several associations among energy use, economic growth, and CO2 emissions.

A study was carried out by Dihor, Alekseeva, and Lomtatidze [22] to examine the link between the expansion of the Malaysian economy and the use of natural gas. Studied were data sets spanning 1971–2012. Capital creation, trade openness, and foreign-direct investment (FDI) served as the control variables in the research. A number of variables, including FDI, NG use, trade openness, and capital creation, were shown to have a clear and direct beneficial outcome on economic growth in this Malaysian research. Economic growth, FDI, and natural gas consumption are all interrelated, and the result of this study show that feedback assumption is a key component in these linkages.

Natural gas reserves throughout the globe were studied in depth by Li, She, Gao, Li, Yang, and Shi [23] to determine their current state, trade patterns, and future prospects. A comprehensive review of the history, present situation, trends, and problems of China's natural gas sector was presented in the report. Afterwards, it provided a supply and demand assessment and projection. In the end, the study produced a set of long run, realistic recommendations and strategies. The upshots that followed are detailed below. (1) A quantity of about 650 billion cubic metres of natural gas would be utilised in 2030, in line with the technique that uses the comprehensive energy elasticity coefficient. (2) Rising domestic use of natural gas is outpacing rising output by a wide margin. Reforms on the energy supply side, industrialization, and urbanisation are the main causes of this. The expansion of the natural gas business is therefore beset by a number of obstacles. Thirdly, increasing domestic natural gas storage and output requires better natural gas discovery and development. (4) To avoid becoming too reliant on other nations, it is essential to constantly diversify the sources of natural gas procurement. Fifthly, we need to move quickly to set up a national interconnection system and centre. (6) China has to streamline its natural gas pricing system, ease restrictions on industrial and seasonal consumption over time, and enhance its domestic sales forecast generally.

In line with the research, a number of studies have looked at how energy consumption—and more especially the use of natural gas—affect the economic advancement (growth) of regions like sub-Saharan Africa. Nevertheless, the majority of studies examining energy consumption have concentrated on the use of fossil fuels and how it relates with economic growth. To promote the environmentally beneficial use of clean and renewable energy for productive purposes, it is imperative to examine how natural gas, often called a transitional fuel, has affected the economic progress of sub-Saharan African states.

3. METHODOLOGY

The research is based on the Biophysical theory proposed by Kardashev. The argument posits that energy sources i.e. natural gas play a crucial role in enhancing productivity and fostering economic growth within a nation. In their research on the influence of natural gas consumption on economic advancement (growth) in Africa, Akokaike, Adenikinju, Ekpe, Eleri, Ajulo, and Gini [1] have forth an analytical methodology that supports this assumption. Nevertheless, this research was substantially altered to include and accommodate all the factors of relevance. The model is represented in its functional, explicit, and natural log forms as follows:

$$RGDP_{it} = f\left(TNGC^{\beta_1}{}_{it},\ IGC^{\beta_2}{}_{it},\ RGC^{\beta_3}{}_{it},\ \mathrm{TGC}^{\beta_4}{}_{it}\right) \quad (1)$$

To facilitate the estimation of equation 1, it is express thus:

$RGDP_{it}$ =

$$\beta_0 + \beta_1 InTNGC_{it} + \beta_2 InIGC_{it} + \beta_3 InRGC_{it} + \beta_4 InTGC_{it} + \mu_{it} \quad (2)$$

Where: $RGDP_{it}$= Real Gross Domestic Product; $TNGC_{it}$= total natural gas consumption; IGC_{it}= industrial gas consumption, RGC_{it}= residential gas consumption, TGC_{it}= Transport sector gas consumption, i= number of nations/cross section (Algeria, Egypt, Equatorial Guinea, Ghana, Nigeria and Tunisia), t = time frame, β_0 = constant variable in the model, β_1 = parameter of total natural gas consumption, β_2 = parameter of industrial gas consumption, β_3 = parameter of residential gas consumption, β_4= parameter of price of natural gas, In = natural logarithm, μ_t = disturbance or error term

The six nations mentioned above were chosen based on the quantity of gas generated and utilised. The data for this research was obtained from the International Energy Agency and the World Bank.

3.1 Method of Data Analysis

The static or long-run models of panel analysis are calculated on the premise of two assumptions. The first assumption accommodates the variability of the many units in the model. In other words, the various units are constant and enable the consideration of the distinct result of the units in the model or the distinct result of different nations (the fixed effect model). The second assumption of the static panel model posits that the variance among member nations is stochastic and independent of the predictor or independent variable utilised in the model. A benefit of random effects is that it allows for the estimation of time-invariant variables. Similar to the OLS estimate, the random effects model assumes that the unobserved nation effects are not linked with the explanatory factors. Based on this premise, the random effects model is not appropriate for addressing the issue of endogeneity. The fixed effects model addresses the issue of endogeneity by considering the presence of unobserved heterogeneity. The Feasible Generalised Least Square (FGLS) estimator is utilised to estimate the random effect model due to its ability to account for the homogeneity of individual nations [24]. The Least Square Dummy Variables (LSDV) estimator is utilised to estimate the fixed effect model, since the fixed effect accounts for variations in socio-economic and political arrangements across nations. Both the random effects and fixed effects estimators are limited to analysing static models and do not include the dynamic or short-term upshots of regional integration on economic advancement. The FGLS (Feasible Generalised Least Squares) and LSDV (Least Squares Dummy Variable) estimators are not suitable for the dynamic model due to the potential bias and inconsistency in the resultant parameter estimations. Adding the lagged dependent variable to the explanatory factors leads to issues of autocorrelation and endogeneity, which cannot be addressed by estimating random or fixed effects models. In order to address these issues in econometrics, the research employs a dynamic panel model estimation utilising the Generalised Methods of Moment (GMM), specifically the difference GMM method established by Arellano and Bond (1991). The Husman test and other diagnostic tests are performed to ascertain the optimal model.

3.2 Random Effect Specification

Pooled regression model:

$$Y_{i,t} = X'_{i,t}\beta + \delta + \mu_i + \pi_{i,t} \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where: $Y_{i,t}$ = vector of dependent variable ($RGDP_{it}$); $X'_{i,t}$ = matric of independent variables ($TNGC_{it}$, IGC_{it}, RGC_{it}, PNG_{it}) ; δ = the common intercept across nations and the disturbance term is $\varepsilon_{i,t} = \mu_i + \pi_{i,t}$. Equation 3 is sometime called error component model because the $\varepsilon_{i,t}$ term is decomposed.

The random individual differences may be divided into two components: the constant component, δ, which represents the population average, and the random component, μ_i, which represents the random variation, also known as the random effect.

The term μ_i represents the random heterogeneity that is particular to the cross-section information or observation, often known as the nation effect. This heterogeneity remains constant across time and is independent of any temporal changes. In contrast to the fixed effect model (model 3), the number of parameters that need to be estimated is reduced.

The major assumption of model (3) is that $\mu_i \neq X'_{i,t}$ [24].

Fixed effect model:

$$Y_{i,t} = X'_{i,t}\beta + \varepsilon_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$\varepsilon_{i,t} = \alpha_i + \gamma_t + \eta_{it}$ …… (5)

Where:

α_i is the unobserved cross sectional specific effects ; γ_t is the unobserved time specific effects
η_{it} is the common cross section time series effect
$Y_{i,t}$ is the dependent variable in the models
$X'_{i,t}$ is the matrix of the independent variables and control variables in the models

The major assumption of model (3) that is, $\mu_i = X'_{i,t}$. All of the expected differences in behaviour between individuals, often called individual heterogeneity, are represented by the intercept. That is, to account for the variation across nations, the individual effects or intercepts are considered as variables [24].

4. RESULTS

The analysis of the six nations presented in Table 1 reveals that all of them exhibited substantial volatility in their real GDPgrowth, total natural gas consumption, gas consumed by the industrial sector, households, and natural gas consumed by the transport sector during the specified period, as indicated by their mean and standard deviation values. The volatility is further shown by the lowest and greatest values of actual economic growth and natural gas consumption in the nation throughout the time being studied.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Rgdp	192	6.008	13.5	-9.11	149.97
Tngc	192	157161.56	216931.01	40	904935
Igc	192	61295.672	80786.39	20	380597
Rgc	192	43556.255	84670.152	10	460755
Tgc	192	10515.136	12028.414	8	63585

Source: Researcher's Computation (Stata 17)

Table 2. Pair wise correlation result

Variables	(1)	(2)	(3)	(4)	(5)
(1) rgdp	1.000				
(2) tngc	-0.145	1.000			
	(0.044)				
(3) igc	-0.136	0.914	1.000		
	(0.060)	(0.000)			
(4) rgc	-0.127	0.832	0.553	1.000	
	(0.078)	(0.000)	(0.000)		
(5) tgc	-0.177	0.661	0.506	0.675	1.000
	(0.014)	(0.000)	(0.000)	(0.000)	

Source: Computed Result (Stata 17)

Table 3. Unit roots test result – philip peron procedure

Variable	PP Statistic @ level	PP Stat @ 1st Difference	Prob @Level	Prob @ 1st Difference	Decision
RGDP	-8.05		0.00		Stationary@ level
LnTNGC	0.50	-26.27	0.69	0.00	Stationary@ 1st difference
lnIGC	0.75	-24.80	0.77	0.00	stationary@ 1st Difference
LnRGC	-2.30	-24.09	0.01	0.00	Stationary@ level
Ln TGC	0.05	-28.93	0.52	0.00	stationary@ 1st Differnece

Source: Researcher's Computation (Stata 17)

Table 4. Kao test for cointegration/long run link

Test	Statistic	P-value
Modified Dickey-Fuller	-9.3988	0.0000
Dickey – Fuller	-6.1717	0.0000
Augmented Modified Dickey-Fuller	-4.0540	0.0000
Unadjusted modified Dickey-Fuller	-11.3571	0.0000
Unadjusted Dickey-Fuller	-6.4212	0.0000
H_0: No cointegration	Ha: All panels are cointegrated	

Source: Researcher's Computation (Stata 17)

Table 5. Pedroni test for cointegration

Test	Statistic	P-value
Philip – Perron	-7.3605	0.0000
Augmented Dickey – Fuller	-6.4908	0.0000
H_0: No cointegration	Ha: All panels are cointegrated	

Source: Computed Result (Stata 17)

Table 6. Long run panel ARDL result

Variable	Coefficient	Z –value	P-value
LnTNGC	-5.09	-1.89	0.05
Ln IGC	2.13	1.06	0.29
LnRGC	2.13	2.07	0.04
LnTGC	0.26	0.52	0.60

Source: Researcher's Computation (Stata 17)

The correlation analysis shown in Table 2 indicates that there is no substantial evidence of a strong association among the independent variables, namely natural gas usage. Neither of the two variables has a correlation value of 0.95. This suggests that all of the independent variables have the potential to interact insidethe equation for economic advancement. Therefore, the likelihood of multicollinearity among the independent variables is negligible.

The unit roots test result, done applying the Philip – Perron approach and presented in Table 3, indicates that both real economic growth (LnRGDP) and residential gas consumption (LnRGC) were stationary at level i(0). This indicates that the null hypothesis of the existence of unit roots was rejected without the need for differencing. The variables Total natural gas consumption (lnTNGC), industrial gas consumption (LnIGC), and Transport sector gas consumption (LnTGC) achieved stationarity after being differenced once (i(1)). This indicates that the null hypotheses about the existence of unit roots for the variables were rejected after applying the first difference. The upshots also indicate that the variables under investigation exhibited varied levels of stationarity. The use of the Panel Autoregressive Distributed Lag (PARDL) approach was prompted by this advancement for estimating the growth model. We estimate the long-term connection between the dependent and independent variables applying the Kao and Pedroni test for Cointegration.

The result from Tables 4 and 5 indicate that the null hypothesis of no long-term association between natural gas consumption and economic advancement was rejected for all the panels in both the Kao and Pedroni tests. This provides empirical proof that a durable and enduring link is present for all the panels being studied.

Based on the result provided in Table 6 of the long-term panel autoregressive distributed lag (ARDL) analysis, there is a strong unfavourable correlation between total natural gas consumption and economic advancement in the nations that were studied (Equatorial Guinea, Egypt, Tunisia, Nigeria, Ghana, and Algeria). This suggests that the usage of natural gas hindered economic advancement in these nations. This finding aligns with previous research conducted by Mwoya and Derick [25] and Lakasa [26], which observed a unfavourable correlation between natural gas use and

economic advancement. The poor gas infrastructure and utilisation in developing nations, particularly in sub-Saharan African nations, may be identified as the main cause of this outcome.

The usage of industrial gas has a strong and favourable outcome on the nations being analysed. This suggests that higher utilisation of industrial gases is associated with enhanced economic activity and economic advancement, while reduced consumption of industrial gases hinders economic activities and economic growth. This finding aligns with previous research conducted by Abdul and Liang [13], which documented a favourable correlation between industrial gas use and economic advancement.

The residential petrol consumption in Algeria, Tunisia, Nigeria, Ghana, Egypt, and Equatorial Guinea has a favourable and considerable outcome on economic advancement in these chosen oil-producing nations. This suggests that an increase in the amount of petrol utilised by families directly affects the economic activity and economic advancement of the nations being studied. It is imperative to acknowledge that a rise in household petrol consumption has the potential to mitigate environmental degradation and enhance the performance of small and medium-scale companies, which are crucial drivers of economic growth and development.

The long run outcome also point out that the use of natural gas for transportation has a favourable, albeit statistically negligible, outcome on economic advancement in the chosen nations. This outcome aligns with our initial prediction and demonstrates that higher petrol use for transportation drives economic activity and promotes economic advancement. Nevertheless, the lack of importance of this variable may be attributed to the limited use of petrol in the transportation industry, particularly in developing nations, namely the nations in sub-Saharan Africa, over the years.

Table 7 shows the results of the short run panel Error Correction ARDL model, which indicate that the amount of natural gas consumed (LnTNGC) significantly affects the economic growth of the nations under consideration (Equatorial Guinea, Egypt, Tunisia, Nigeria, Ghana, and Algeria). This suggests that these nations' use of natural gas contributed to their economic growth. This confirms what other studies have shown: that applying natural gas contributes favourably to economic advancement [27,28,1]. The strong demand for gas infrastructure and utilisation in emerging nations, particularly sub-Saharan African nations, may be seen as the main reason for this outcome. This is notably evident in the areas of power generation and exports.

In the short run, the use of industrial gas (LnIGC) has a favourable and substantial outcome on the nations being analysed. This suggests that higher utilisation of industrial gases is associated with enhanced economic activities and economic advancement, while a reduction in industrial gas consumption hampers economic activities and economic growth. This finding aligns with previous research conducted by Abdul and Liang [13], which documented a favourable relationship between the use of industrial gas and economic growth.

The short run error correction analysis also indicates that household petrol consumption (LnRGC) has a unfavourable and statistically negligible outcome on economic growth in the chosen oil-producing nations of Algeria, Tunisia, Nigeria, Ghana, Egypt, and Equatorial Guinea. This suggests that a rise in consumers' petrol consumption has an unfavourable influence on economic activity and economic advancement in the nations being studied. This outcome may be ascribed to the reduced level of residential or household gas use, which in turn curtails economic activity and hampers economic growth.

The long run outcome also point out that the use of natural gas for transportation (LnTGC) has a favourable but statistically negligible outcome on economic growth in the chosen nations. This outcome aligns with our initial hypothesis and demonstrates that higher petrol use for transportation drives economic activity and promotes economic growth. Nevertheless, the lack of importance of this variable may be attributed to the limited use of petrol in the transportation industry, particularly in emerging nations, namely the sub-Saharan African nations, over the years.

Table 7. Short run panel ARDL result

Variable	Coefficient	Z –value	P-value
ECT	-0.64	-7.95	0.00
LnTNGC	3.65	2.95	0.00
Ln IGC	7.07	2.16	0.03
LnRGC	-4.35	-1.37	0.17
LnTGC	0.59	0.26	0.80
Constant	10.43	7.56	0.00

Source: Researcher's Computation (Stata 17)

Table 8. Hausman test

Variable	Coefficients			
	(b) Mg	(B) pmg	(b-B) Difference	Sqrt(diag(v_b-V_B)) S.E.
Lntngc	-36.97	-5.09	-31.88	25.21
Lnigc	27.56	2.14	25.43	21.96
Lnrgc	3.98	2.13	1.85	8.16
Lntgc	3.14	0.28	2.86	5.61

b = consistent under H_0 and H_a: obtained from xtpmg: B= inconsistent under H_a, efficient under H_0: obtained from xtpmg. Test: H_0: difference in coefficients not systematic. chi2(4) = (b-B) ' [(V_b-V_B) ^ (-1)] (b-B) = 4.64; Prob>chi2 = 0.33

The presence of the Error Correction Term (ECT) indicates the existence of a long run nexus between natural gas consumption and economic growth in Algeria, Tunisia, Nigeria, Ghana, Egypt, and Equatorial Guinea over the research period.

The Hausman Test result indicates that the null hypothesis, which states that there is no systematic difference in coefficients, is accepted. This suggests that the influence of natural gas use on economic growth is consistent across the nations being studied. Oil producing nations in Sub-Saharan Africa suffer from inadequate infrastructure and a lack of political will to ensure that crude oil production contributes to economic growth. The nations' reliance on foreign technical expertise and investment capital has diminished the profits derived from natural gas extraction. The line graphs indicate that natural gas usage in most nations has been consistently low or subject to substantial fluctuations throughout the years.

5. FINDINGS

The ARDL panel analysis reveals that, in the long run, the overall natural gas consumption has a detrimental outcome on economic growth. However, in the near term, the upshot of natural gas consumption is favourable and noteworthy. This suggests that the overall use of natural gas hindered long-term economic growth but promoted short-term economic growth. The long-term outcome aligns with the previous outcomes made by Mwoya and Derick [25] and Lakasi [26], whereas the short-term outcome is consistent with the results of Obsatar et al [27] and Akokaike, Adenikinju et al. [1]. Many nations worldwide are transitioning from fossil fuels to clean energy, with natural gas playing a crucial role as a transitional energy source due to its environmentally beneficial effect. Furthermore, natural gas is more cost-effective, making it a more affordable option for a larger number of customers in comparison to fossil fuel.

Industrial gas consumption has positive and significant impact on economic growth both in the long run and short run. This implies that industrial natural gas utilization has direct impact on economic activities and economic growth of the selected countries of Algeria, Egypt, Ghana, Equatorial Guinea, Nigeria and Tunisia. This result is in consonance with earlier study by Abdul and Liang [13] which found direct effect of industrial gas consumption on economic growth. The low price of natural gas compared to fossil fuel may reduce cost of production and increase output of firms. This will definitely improve economic performance of the countries.

In the long term, there is a strong and favourable relationship between residential gas demand and economic advancement (growth). However, in the short run, the influence of residential gas demand on economic growth is unfavourable and

not statistically substantial. The prevalence of poverty in Africa, along with the limited gas infrastructure in many of the nations studied, likely had a role in the adverse effects of home gas use on short run economic growth. Enhance residential gas use to promote environmental conservation and stimulate the expansion of small and medium-sized enterprises. Nevertheless, the substantial poverty rates and lack of essential gas infrastructure have had a detrimental impact on the link between domestic gas consumption and economic advancement in emerging nations.

The usage of petrol in transportation has a beneficial outcome on economic growth, both in the short run and in the long run. However, this effect is not statistically substantial at a 5 percent level of significance. Consequently, the research finds that the effect of petrol consumption by the transportation industry on economic advancement is minimal over the time under investigation. It is imperative to acknowledge that the majority of developing nations have not yet obtained modern technology in the transportation industry that relies on natural gas as its energy source. Gas-powered automobiles and trains had not yet been utilised in Africa. This may have influenced the impact on the economic progress of these nations.

6. CONCLUDING REMARKS

This study investigated the impact of natural gas consumption by the industrial sector, residential/households and transport sector on economic growth of selected countries in Africa (Algeria, Egypt, Equatorial Guinea, Ghana, Nigeria and Tunisia) over the period 1990 – 2021. In order to achieve this objective, data on growth rate of gross domestic product (RGDP), total natural gas consumption, industrial gas consumption, residential gas consumption and natural gas consumed by the transport sector of the selected countries were sourced from the World Bank Development Indicators and International Energy Agency (IEA) and analyzed using panel Autoregressive Distributed lagged (ARDL) method. The results of our analysis show that: Total natural gas consumed has negative and significant impact on economic growth in the long run but positive and significant effect on economic growth of the selected countries in the short run. Industrial gas consumption has positive and significant impact on economic growth of the selected countries both in the short and long run. Residential gas consumption has positive and significant impact on economic growth in the long run but negative and insignificant effect on economic growth in the short run. Natural gas consumed by the transport sector has positive but insignificant effect on economic growth of the selected countries over the period under study. The impact of natural gas consumption on economic growth for all the countries under study does not vary. That a long run relationship exists between natural gas consumption and economic growth among the countries been investigated. Based on these findings, the study recommended that governments of African countries under investigation should encourage natural gas consumption in the industrial, transport and households by building gas infrastructure and investment in the oil and gas sector in order to stimulate economic in the sub region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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