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Beyond Economic Growth: Does Natural Gas Consumption and Price Promote Trade in Top Gas Producing African Nations?- An Evidence from Time Series Analysis

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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

The study examined the role of natural gas consumption and price in enhancing trade among top gas producing nations in Africa. To accomplish the study's objective, data on natural gas consumption, natural gas price, and gasoline motor fuel (used as a reference variable) was gathered from the World Bank and the International Energy Agency. These data were then analysed using the panel ARDL methodology to examine the relationship between trade openness and natural gas consumption and price in the six leading gas producing nations in Africa – Nigeria, Angola, Algeria, Egypt, Libya, and Gabon. The findings of our study indicates that a rise in the price of natural gas has a positive impact on the trade and growth levels in the economies of the leading gas-producing nations in Africa. As the price rises, there is a corresponding increase in commerce,

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particularly in exports. This leads to a growth in real GDP and a greater contribution of the energy sector to the overall economic development. The increase in trade and economic development leads to greater trade openness, with the price of natural gas playing a crucial role in this improvement. The trade facilitation in the chosen African nations that produce natural gas was greatly hindered by the high prices of natural gas (natural gas consumption) and the usage of petrol for vehicle fuel. Based on these findings, the study suggested that: liberalising the oil and gas sector in gas producing nations would be beneficial to their economy. This would encourage competition, stabilise prices, strengthen gas infrastructure, and boost trade and development in gas producing nations in the African sub region.

Keywords: Trade openness; natural gas consumption; natural gas price and gasoline motor fuel.

1. INTRODUCTION

Gas-producing African nations, like established and rising economies, have used various methods to extract natural gas. Natural gas is used not just for generating electricity but also for many applications i.e. fertiliser production, heating, transportation, and cooking. Consequently, a nation that has a larger use of natural gas will see more rapid economic growth. The reason for this is that the use of natural gas is directly correlated with global economic development and the rise in national GDP [1]. The connection between price and natural gas usage in comparison to their impact on economic performance has been the subject of substantial interest throughout the industrial period. Substantial volumes of natural gas are generated to attain economies of scale, resulting in the growth of several economies. The use of natural gas has a significant impact on a country's economic growth and development [2].

As a resource-dependent industry, natural gas consumption comprises both domestic sales and the import/export of the commodity to meet various demands [3]. According to Egging and Holz's [4] global gas supply chain model, after buying natural gas from producers, merchants may either utilise it at home or sell it to other countries. In the natural gas market, two main options exist: LNG (liquefied natural gas) from offshore and PNG (onshore pipeline natural gas). Because less developed nations lack the necessary infrastructure, there is a limited need for natural gas from them. Consequently, the majority of the natural gas generated is exported to developed and industrialised nations, where it is required for industrial production and home consumption.

Algeria, Nigeria, Angola, Egypt, Equatorial Guinea, Gabon, and Libya are the leading gas-producing nations in Africa due to their substantial natural gas reserves and high production levels. In congruent with Statista, Africa's natural gas consumption in 2021 amounted to around 5185 billion cubic feet, derived from a production of 259 billion cubic metres. Additionally, it states that of the total production of 249 billion cubic metres in 2022, 115 billion standard cubic metres of natural gas were exported. Algeria, Nigeria, Egypt, Angola, Equatorial Guinea, and Libya exported 48,920 billion standard cubic metres (bscm), 32,190 bscm, 12,043 bscm, 7,540 bscm, 5,737 bscm, and 2,479 bscm respectively. The occurrence of conflict between Russia and Ukraine, likewise the Covid-19 epidemic, had an adverse influence on global natural gas production and export.

As a consequence, Africa's net gas exports decreased to 12 percent over the reviewed period. These statistics indicate that natural gas, apart from crude oil, continues to be a significant export commodity in Africa. While the overall amount of commerce had a little increase, particularly in imports, the majority of exported goods consisted of raw materials. As an example, the whole value of exports (Free on Board) amounted to US$ 310,083 million, while the entire value of imports (Cost, Insurance, and Freight) reached US$ 305,528 million. In congruent with the World Bank [5], a total of 4,536 goods were exported to 227 nations at the HS6 digit level. Additionally, 4,624 items were purchased from 236 nations. In light of this situation, it is crucial to analyse the extent to which the exportation of natural gas has bolstered trade growth in the leading gas-producing nations in Africa from 1990 to 2021.

2. LITERATURE REVIEW

The Heckscher–Ohlin model, sometimes known as the H–Ohlin model, posits that variations in factor endowments are the primary determinant of the global trade patterns. The theory posits that nations are inclined to export items that need a high utilisation of locally available resources, while importing products that require resources that are scarce locally. The H–O model is owing to the following assumptions: (a) Labour and capital can freely move between sectors, resulting in equal factor prices across sectors within a nation. (b) There is a difference in the amount of labour and capital between two nations, indicating a difference in endowments. (c) Technology is assumed to be the same across nations in the long term. (d) Tastes are assumed to be the same across nations. Therefore, the presence of fixed and limited natural resources might serve as a basis for comparative advantage, influencing the character of international commerce.

Consistent with this hypothesis, Leamer [6] found that the abundance of petroleum results in a surplus of crude oil and natural gas being exported, whereas the abundance of coal and other mineral resources leads to a surplus of raw materials being exported. The Heckscher-Ohlin theory has been expanded by comprise other variables, i.e. transportation costs, economies of scale, and government policy, which also impact comparative advantage. Distance from global markets may substantially impact the viability of natural resources that are voluminous, i.e. natural gas, especially when transportation expenses are substantial. In the presence of challenging or technically intricate extraction processes, the inclusion of complementary inputs i.e. technology, money, and trained labour becomes crucial in a natural resource industry. An increase in international trade between resource-rich and resource-poor countries has resulted from the rising demand for natural gas as an energy source and the worldwide distributional inequality of natural gas and other mineral resources.

Through the use of the ARDL approach, Bulkani and Chandra [7] examined the relationship between labour and capital, natural gas consumption, and exports from 1980 to 2018. The upshots show that natural gas use in Indonesia slows economic development, even while exports, capital consumption, and labour consumption all rise. The report recommended that Indonesia should aggressively manage its natural gas supplies and availability, while also making a deliberate effort to develop its workforce resources and provide a sufficient planning timeframe.

In their study, Sakiru and Muhammad [8] conducted a thorough examination of the correlation between economic growth and natural gas consumption in Malaysia from 1971 to 2012. They expanded their analysis by comprise factors i.e. foreign direct investment, capital, and trade openness. The stationary features of the series were investigated by means of the structural break unit root test. To look at the link between the variables over the long run, the researchers conducted a combined cointegration test. In order to guarantee longevity, the ARDL limits testing method was used to investigate the possibility of a long-term connection when structural disturbances were present. This study found that natural gas consumption, FDI, capital formation, and trade openness all contribute positively to economic growth in Malaysia. The upshots indicated that there is a feedback hypothesis between the natural gas utilisation and economic development, FDI and economic growth, and FDI and natural gas consumption. The upshots are discussed together with the policy implications.

Akinlo and Apanisile [9] examined the influence of oil price volatility on the economic development of 20 Sub-Saharan African nations between 1986 and 2012. The nations were categorised into Group A and Group B. Group A comprises 10 nations that export oil, while Group B comprises sub-Saharan African nations that do not export oil. The study used panel data. The estimate process used panel pooling OLS, panel fixed effect model, and generalised technique of Moment model for both oil exporting and non-oil exporting nations. The panel A model estimate for oil exporting nations revealed a significant and favourable impact of OPV on their economic development. The outcomes from panel B, which comprises nations that do not produce oil, indicate that the fluctuation in oil prices has a positive but not substantial effect on economic growth.

For their 2020 study, Li, Yang, She, Gao, Li, and Shi analysed the world's natural gas resources in their present form, trade patterns, and projected trends. The research conducted a comprehensive analysis of the developmental process, present status, trends, and challenges in the natural gas sector in China. It subsequently provided a prospective analysis and assessment of the demand and supply dynamics. The upshots of the analysis were as follows: (i) It is estimated that 650 billion cubic metres of natural gas would be used globally in

2030. (ii) Owing to a number of factors, including industrialization, urbanisation, and energy supply side reform, the growth rate of domestic natural gas consumption will be much higher than that of production. Still, a number of problems impede the natural gas industry's growth. (iii) In order to ensure the expansion of domestic natural gas storage and production, it is imperative to bolster natural gas exploration and development. (iv) To reduce the risk of an unsustainable growth in dependence on other countries for natural gas, the development of diverse import routes should continue. Accelerating the establishment of a hub and national system of dynamic connectivity is necessary. (vi) China should improve overall sales guidance in the domestic market, gradually relax limits on industrial and seasonal consumption, and simplify the natural gas pricing structure.

In their study, Nwabueze, Ogbonna, and Nwaozuzu [10] examined the causal effects of natural gas consumption, natural gas price, crude oil price, FDI, and per capita GDP in Nigeria. For their investigation, they used time series data spanning from 1990 to 2020 using the Vector Error Correction model (VECM). There is a strong positive correlation between natural gas consumption and economic growth (measured by per capita GDP) in Nigeria, according to the VECM estimate, the Granger causality test, and the Variance decomposition test. As a result, there is a clear link between the rise in natural gas consumption in Nigeria and the adoption of economic policies that encourage the country's manufacturing sector. In the end, FDI had no impact on the consumption of natural gas, while crude oil price fluctuations had a substantial influence. These upshots suggest that, if all other things stay the same, the amount of foreign direct investment (FDI) flowing into Nigeria is primarily determined by changes in the global price of crude oil, not by Nigeria's use of petrol.

Udo, Idamoyibo, Inim, Akpan, and Ndubuaku [11] investigated the co-integration and causal connexion between energy consumption and economic growth in Nigeria's agricultural, manufacturing, and service sectors. Owing to quarterly data spanning from 2000Q1 to 2018Q4, the analysis revealed a combination of outcomes. Firstly, there was a co-integrating link observed between economic growth and sectorial value creation. Secondly, a bidirectional causality was found between liquefied natural gas and energy consumption. Lastly, a unidirectional causality was identified between economic growth and petroleum consumption.

In their study, Mwoya and Derick [12] assessed the effect of natural gas utilisation on the economic advancement of Tanzania throughout the period of 2004 to 2016. The model accounted for economic growth (measured by real GDP per capita), natural gas consumption, labour supply, and capital as controllable variables. The research's empirical results indicate that the economic impact of natural gas use throughout the study period is characterised by a high level of uncertainty. The average natural gas consumption is estimated to fall within a range that spans from negative to positive values, with a 95 percent level of confidence. Consequently, it is improbable that the utilisation and market need for natural gas would have a substantial influence on the economic advancement of the nation. The upshots, however, indicated that the availability of labour force had a positive effect on economic development. In order to impact economic growth, the report recommended augmenting the labour force in the Tanzanian economy, likewise enhancing and reinforcing regulations related to the utilisation of natural gas, comprising gas power generation, industrial use, and the establishment of an efficient natural gas market.

Foye and Benjamin [13] looked analysed the effects of natural gas use on the financial health of a number of countries in sub-Saharan Africa between 1998 and 2017. The Toda and Yamamoto's lag augmented vector autoregressive method for heterogeneous mixed panels, as shown in Emirmahmutoglu and Kose, is used in data analysis together with dynamic heterogeneous approaches. The research discovered a substantial and enduring correlation between the actual gross domestic product and the usage of natural gas. The research also found that there is a notable and favourable impact on economic performance in the near term as a result of increased natural gas usage. Furthermore, the upshots support the conservative hypothesis for the selected sub-Saharan African countries. Hence, it is logical for the chosen sub-Saharan African nations to develop and advocate for cost-efficient and environmentally friendly energy and environmental strategies that will boost the utilisation of natural gas without compromising long-term economic performance.

In their study, Itoua, Manguet, and Mouanda-Mouanda [14] examined the influence of gas production, gas utilisation, and gas flaring on the economic development of the Republic of Congo from 2006 to 2019. The unit root test outcomes indicate that the majority of variables are stationary at the level and thus have zero order integration. However, labour input is stationary at the first difference and has first order integration. The Johansen cointegration test indicates that all time series exhibit cointegration and possess a stable long-term equilibrium connection. The research also conducted the Granger-causality test, which demonstrates that only gas production and gas utilisation are causally linked to economic development in our investigation. The OLS regressions indicate that gas output has a negative and substantial influence on GDP, whereas gas utilisation has a favourable and substantial effect on GDP.

Jahangir and Dural [15] investigated the impact and causal link between natural gas and crude oil on the Caspian Sea region's economic growth. Using time series data spanning from 1997 to 2015, the researchers used the ordinary least square (OLS) technique to perform a Granger causality test in this study. Determining the impact and causal link between natural gas and crude oil on economic growth was the goal. The OLS approach yielded results that indicated the substantial influence of natural gas and crude oil on the region's economic growth. Furthermore, it is clear from doing a causality test that the GDP and the price and export of crude oil have a unidirectional Granger causation connection. This suggests that the price and export of crude oil may be predicted using GDP. But the opposite is not true—it is impossible to predict GDP using the price and export of crude oil. Surprisingly, this natural gas and GDP trend seems unlikely. Natural gas and GDP have a unidirectional but opposing causal link. It may be possible to forecast changes in GDP by using the Granger causal link between natural gas exports and prices. Nevertheless, GDP is unable to predict changes in crude oil prices or export volumes.

Tamba and Lélé [16] examined the influence of gasoline energy use on economic development in Cameroon using an autoregressive vector (VAR) model and Wald test to assess causality. The estimated outcomes indicate that there is no enduring correlation among the factors examined in the research. A bidirectional causal link between petrol consumption and economic development is seen in Cameroon. The estimated outcomes indicate that without well-defined and implemented energy regulations, it is not feasible to reduce petrol use as a means to sustain Cameroon's economic development.

Reuben [17] conducted an empirical research to examine the factors that influence the practice of natural gas flaring in Nigeria. The research used the ARDL bounds test to cointegration technique to investigate the factors influencing natural gas flaring in Nigeria. Secondary data spanning the period of 1984-2013 was applied for this purpose, with a particular emphasis on long-term analysis. The empirical outcomes have revealed many key factors that determine the occurrence of natural gas flaring in Nigeria. These factors comprise the penalty imposed for flaring, the level of crude oil production, the price of natural gas, the degree of marketization of natural gas, and the insufficient infrastructure for natural gas. The primary factor driving the rise in natural gas flaring is the growth in crude oil output. Conversely, the most effective measure for reducing gas flaring is the proper marketization of natural gas. The main outcome of this study is that the adoption of policies aimed at achieving the most efficient reduction of natural gas flaring may lead to a long-term decrease in natural gas flaring and help Nigeria reach the 2030 deadline set by the World Bank to stop regular natural gas flaring.

Balitskiy, Bilan, Strielkowski, and Štreimikienė [18] investigated the correlation between natural gas and the economic progress of twenty-six European Union nations. The research comprised data from the time frame spanning 1997 to 2011. To conduct a two-way statistical inquiry, the authors used an error correction model (ECM) to examine the causal links between the variables. The study of association data indicated a strong and negative link between natural gas and production growth. Conversely, there was a significant positive correlation between output growths with natural gas in the studied nations.

Solarin and Ozturk [19] conducted a study to examine the correlation between the use of natural gas and the economic development of twelve OPEC nations. The research comprised data from the time span of 1980-2012. The use of the panel Granger causality approach revealed that the OPEC nations exhibit bi-directional causal links between natural gas and economic development. Regarding the individual levels, the research found uni-directional causal links and confirmed the growth impact in Saudi Arabia, Iraq, Libya, Kuwait, and Nigeria. Moreover, the presence of a conservation effect was seen in the nations of Iran, Venezuela, Algeria, and the United Arab Emirates. Regarding the other nations, the analysis was unable to identify any causal links between natural gas and economic development.

In their study, Shahbaz, Lean, and Farooq [20] investigated the impact of natural gas utilisation on economic activity and development in Pakistan. The research used data spanning from 1972 until 2010. Using ARDL bound testing, the analysis found that natural gas (NG) has a considerable impact on the economic growth of the nation. This suggests that increasing the use of NG will have favourable effects on economic progress. Moreover, the outcomes of the causative analysis indicate the presence of a one-way causal link between NG and production growth, with the causation running from NG to economic development in Pakistan.

In their analysis, Belke, Dreger, and De Haan [21] comprised energy prices as the intermittent variable to investigate the causal connection between energy use and economic development in 25 OECD nations. The research used data from 1981 to 2007. The outcomes indicate that varying economic advancements in various nations have a substantial influence on the co-integration of actual gross domestic product (GDP) and energy usage. The Granger-causality analysis revealed a reciprocal link between energy use and economic development, supporting the feedback hypothesis. The outcomes further indicated that a rise in energy costs resulted in a decrease in energy use, whereas economic expansion influences energy pricing.

The analysis of previous studies regarding natural gas consumption, economic growth, and trade performance reveals that the majority of research has concentrated on the link between natural gas consumption and economic growth. However, there has been limited investigation into the impact of natural gas or energy consumption and production on international trade between nations. Considering that sub-Saharan African nations rely on income generated from the export of natural resources to support their development, it is crucial to analyse the impact of natural gas production and use on regional commerce.

3. METHODOLOGY

This study is owing to the Heckscher–Ohlin model of international trade, which posits that the pattern of international trade is determined by variations in factor endowments. The theory posits that nations are inclined to export items that need a high utilisation of domestically available resources, while importing products that require resources that are scarce locally. Therefore, the presence of limited and stationary natural resources may provide a comparative advantage that influences the character of international commerce between nations that possess these resources and others that lack them but need them for production and consumption purposes. Owing to this, a trade openness model is specified by comprising variables i.e. natural gas usage, natural gas pricing, and gasoline fuel use (as a control variable):

$$TOP_{it} = f\left(\chi_0 NGC^{\chi_1}{}_{it}, NGp^{\chi_2}{}_{it}, MGC^{\chi_3}{}_{it}, u_{it}\right) \quad 1$$

Since the variables of interest consist of a mix of I(0) and I(1) processes, we employ the panel autoregressive distributed lag (ARDL) method introduced by Pesaran et al. [22]. The panel ARDL model has the benefit and superiority of being applicable regardless of the integration properties of the chosen variables, whether they are entirely I(0), purely I(1), or partially integrated. The import function may be concisely defined as:

$$\ln Top_{it} = \chi_0 + \chi_1 \ln Ggc_{it} + \chi_2 \ln Ngp_{it} + \chi_3 \ln Mgc_{it} + U_{it} \quad 2$$

Where: Ln = Natural logarithm; Top_{it} =. NGC_{it} = Natural Gas Consumption (in billion scf), NGP_{it} = Natural Gas Price (USD per million cubic feet) MGC_{it} = Motor Gasoline Consumption (in millions of litres), χ_0 = intercept; χ_1, χ_2 and χ_3 = coefficient of the independent variables, μ_{it} = error term of the regression; i = Top gas producing nations t = time frame. The data on the aforementioned factors was obtained from the World Bank and International Energy Agency (2022), spanning from 1990 to 2021.

As per the study conducted by Shin et al. (2011), we establish the connection between economic growth and natural gas consumption, as well as the link between the price of natural gas and petrol energy consumption, by using a panel ARDL model.

$$\Delta\ln(Top_{it}) = \beta_0\Delta ln(Top_{it-1}) \beta_1\Delta ln(Ngc_{it-1}) + \beta_2\Delta ln(Ngp_{it-1}) + \beta_3\Delta ln(Mgc_{it-1}) + \sum_{t=1}^{n}\eta_1\Delta 1n(Top_{it-1}) + \sum_{t=1}^{n}\eta_2\Delta 1n(Ngc_{it-1}) + \sum_{t=1}^{n}\eta_3\Delta 1n(Ngp_{it-1}) + \sum_{t=1}^{n}\eta_4\Delta 1n(Mgc_{it-1}) + U_{it} \quad 3$$

Where:
Top_{it} = economic growth, Ngc_{it} = natural gas consumption, Ngp_{it} = natural gas price and Mgc_{it}=gasoline energy consumption for the sample nations, which is assumed to be exogenous to the selected top gas producing nations. The long run coefficients are β_1; β_2; β_3 & β_4 while the short run coefficients are η_1, η_2, η_3& η_4 If cointegration is established then Eq. (3) can be written in a panel error correction model (PECM) as:

$$\Delta lnTop_{it} = \chi_0 + \sum_{t=1}^{n}\chi_1\Delta InTop_{it-1} + \sum_{t=1}^{n}\chi_2\Delta InNgc_{it-1} + \sum_{t=1}^{n}\chi_3\Delta InNGP_{it-1} + \sum_{t=1}^{n}\chi_4\Delta InMgc_{it-1} + \theta ecm_{it-1} + \mu_{it} \quad 4$$

The error correction component, ecm_{it-1}, represents the portion of the system that corrects errors. θ, on the other hand, represents the rate at which the system adjusts from short-term dynamics to long-term equilibrium. In order for a long-term equilibrium to be established between economic growth, natural gas consumption, natural gas pricing, and petrol energy consumption, it is anticipated that the ECM coefficient, will be both negative and statistically significant.

4. RESULTS

The dataset's descriptive statistics were computed using STATA-15. These calculations were performed using the actual values of the variables being examined. Descriptive statistics aids in elucidating the characteristics of the data, both on an individual basis and as a whole. The data may be shown in two distinct tables to effectively convey the variations within the data likewise throughout the full panel. The Table 1 below presents the descriptive analysis outcomes for the dataset, providing an explanation of both the individual and collective aspects of the data that will be used in this research.

In this research, the dataset being studied has a non-zero mean, indicating that no further computations have been performed to adjust the dataset's mean value. The substitution of the logarithmic variable does not comprise any additional calculation in order to achieve a mean of zero and a reasonable standard deviation (representing the extent of variance from the mean). The analysis revealed that natural gas consumption exhibited the highest level of volatility across the data set, but natural gas pricing had the lowest level of volatility, as shown by the standard deviation values both within and across the datasets. When considering the nations collectively, it is evident that the price of natural gas has remained same among them, resulting in a standard deviation value of zero, indicating no variation on a nation-by-nation basis.

Table 1. Summary statistics

Variable	Mean	Std.Dev.	Min	Max	Observations
Ngc overall	449.80	534.18	2.50	2138.00	N =180
between		488.10	6.82	1142.37	n =6
within		292.75	-406.57	1445.43	T =30
Ngp overall	5.76	3.29	2.13	13.41	N =180
between		0.00	5.76	5.76	n =6
within		3.29	2.13	13.41	T =30
Mgc overall	64.40	67.01	0.90	338.00	N =180
between		60.09	1.43	166.57	n =6
within		38.28	-32.17	235.84	T =30
Top overall	67.95	29.46	20.72	178.69	N =180
between		25.16	37.27	106.08	n =6
within		18.36	11.87	140.56	T =30

Source: STATA-15 Computation by Authors

Estimating the link between variables might be challenging if there is a well-established linear link between them. For instance, suppose there exists a linear correlation between a single variable and the other variables. The data underwent pre-estimation data analysis to determine its eligibility for estimating the needed links. The correlation analysis for the dataset being studied is shown in Table 2. The outcomes indicate that there is no absolute linear correlation among the variables in this panel. If the coefficient between two explanatory variables is 0.8 or higher, it indicates a strong likelihood of a perfect linear connection between the variables. In such cases, it is advisable to exclude these variables from the estimate. There is no correlation in this series.

The cross-sectional dependence (CSD) test is a fundamental initial test. When working with panel data, especially with a large number of observations (N). Nevertheless, it is important to acknowledge and consider the existence of cross-sectional dependence in panel analysis, as it is often seen and should not be ignored [23,24,25]. Therefore, assuming that cross-sections are independent might result in substantial problems, such as decreased accuracy of estimators and erroneous test outcomes. The Pesaran [25] cross-sectional dependence (CSD) test is designed for short panels or panel data with a large number of observations (i.e., $N \rightarrow \infty$) and a finite time period.

On the other hand, the Breusch-Pagan LaGrange Multiplier (Breusch-Pagan LM) test assumes that the disturbances in panel models are independent across cross-sections. Christopher F. Baum's findings from 2006 are relevant when the sample size (N) is small and the number of observations (T) approaches infinity. Therefore, the Breusch-Pagan LM test is the suitable test for this inquiry. The Breusch–Pagan Lagrange Multiplier test was performed on the three models shown in Table 3, indicating the existence of cross-sectional dependence. The test unequivocally disproved the null hypothesis of cross-sectional independence at a significance level of 1 percent. This finding highlighted the need of taking into account the delayed interconnections between various entities throughout the countries being studied. Cross-sectional dependency suggests that the effects or connections between variables in the research differ significantly across countries. Hence, formulating conclusions on the reaction to shock in oil producing countries without taking into account the distinctive attributes of each country may result in biassed outcomes.

As Pesaran's CSD test showed that there was cross-sectional dependency among the units, showing that the panel was diverse, the research next conducted panel unit root tests to analyse the stationarity of the variables, assuming that the slopes were heterogeneous. The panel unit roots tests used consist of the Im, Pesaran & Shin test (IPS), Choi test or ADF-Fisher, and Maddala-Wu test or Phillips-Perron (PP)-Fisher chi-square. The outcomes presented in Table 4 indicate that the various panel unit roots tests consistently demonstrated that variables i.e. natural gas price (NGP), natural gas consumption (NGC), motor petrol consumption (MGC), and trade openness (TOP) only achieved stationarity after undergoing the initial differencing process. However, the upshots of the IPS test revealed that the variable TOP was already stationary at level I(0). In addition, the diverse panel unit roots tests exhibited a consistent pattern: the natural logarithm of TOP, NGP, NGC, and MGC only achieved stationarity after undergoing the first differencing process. However, the IPS upshots indicated that the natural logarithm of TOP was stationary at level I(0).

Table 2. Pairwise correlation analysis

Variables	(1)	(2)	(3)	(4)
(1) ngc	1.000			
(2) ngp	0.239***	1.000		
	(0.001)			
(3) mgc	0.486***	0.239***	1.000	
	(0.000)	(0.001)		
(6) top	-0.434***	0.070	-0.614***	1.000
	(0.000)	(0.347)	(0.000)	

Source: STATA-15 Computation by Authors

Table 3. Panel cross-sectional dependence test results

Models	Breusch–Pagan LM cross-sectional independence test statistics i.e., chi2	p-value
Lntop	33.56***	0.00

Source: STATA-15 Computation by Author

Table 4. Second generation (Heterogeneous) panel unit root tests result

Variable	NGC	lnNGC	NGP	lnNGP	MGC	lnMGC	TOP	lnTOP
Im-Pesaran-Shin (IPS)								
Level	-2.28	-2.69	-1.59	-1.38	-2.14	-2.14	-3.05** (-2.69)	-2.74** (-2.69)
First ifference Status	(-2.69) -5.38** (-2.93) I(1)	(-2.69) -5.88** (-2.93) I(1)	(-2.69) -5.32** (-2.93) I(1)	(-2.69) -5.00** (-2.93) I(1)	(-2.69) -4.33** (-2.93) I(1)	(-2.69) -4.94** (-2.93) I(1)	- I(1)	- I(1)
ADF – Fisher								
Level	2.89	8.27	7.46	5.66	1.50	1.59	15.39	15.64
First Difference Status	(1.00) 108.99** (0.00) I(1)	(0.76) 117.70** (0.00) I(1)	(0.83) 82.15** (0.00) I(1)	(0.93) 93.66** (0.00) I(1)	(0.99) 60.90** (0.00) I(1)	(1.00) 69.50** (0.00) I(1)	(0.22) 86.44** (0.00) I(1)	(0.21) 81.93** (0.00) I(1)
PP-Fisher								
Level	3.72	10.87	8.91	6.74	1.44	1.87	18.30	17.23
First Difference Status	(0.99) 174.75** (0.00) I(1)	(0.54) 181.19** (0.00) I(1)	(0.71) 148.23** (0.00) I(1)	(0.87) 131.04** (0.00) I(1)	(0.99) 103.07** (0.00) I(1)	(1.00) 133.54** (0.00) I(1)	(0.11) 184.20** (0.00) I(1)	(0.14) 169.37** (0.00) I(1)

Note 1: (**) and (*) indicates significant at 1% and 5% level respectively. Note 2: While the 5% critical value are in bracket (..) under the IPS test statistics, the p-value are in bracket (..) under the ADF and PP Fisher test statistics

Source: Author's Computation, 2023

Table 5. Second generation (Heterogeneous) panel unit root tests result

Dep. Var	Modified Dickey-Fuller	Dickey- Fuller	Augmented Dickey Fuller	Unadjusted Modified Dickey-Fuller	Unadjusted Dickey-Fuller	Comments
Lntop	-5.12** (0.00)	-4.82** (0.00)	-2.05* (0.02)	-7.96** (0.00)	-5.47** (0.00)	Cointegration

Note: (**) and (*) indicates significant at 1% and 5% level respectively. Source: Author's Computation, 2023

Table 6. Pedroni Panel Cointegration Test Results

Dependent Variable	Modified Phillips-Perron	Phillips-Perron	Augmented Dickey Fuller	Comments
Lntop	1.92* (0.03)	-1.78* (0.04)	-2.02* (0.02)	Cointegration

Source: Author's Computation, 2023

The dataset was subjected to cointegration analysis. Tables 5 and 6 show the upshots of the tests conducted on Kao and Pedroni. The variables in each model of macroeconomic activity have a long-run link, in congruent with the outcomes of the panel cointegration tests. This proves that the explanatory variables may go from a state of short-term disequilibrium to a state of long-term equilibrium.

This study examines the link between the Trade Openness (TOP) of oil-producing countries in Africa and variables such as natural gas usage, natural gas pricing, and gasoline motor fuel use using regression models that utilise dynamic panel data (DPD). Table 7 shows the outcomes of the Arellano-Bond Dynamic Panel Estimation for the LNTOP dependent variable. At first glance, the upshot seems to show that the LNTOP level is higher now because of the prior period's delay. A p-value of less than 1 percent shows that the LNTOP one-period lag coefficient is significantly different from zero. In addition, throughout the time period under consideration, the estimate of natural gas use had a negative coefficient, suggesting that this fuel had a negative impact on the trade openness of oil-producing countries. Nevertheless, even when using a 10 percent significance level, the p-value for the natural gas consumption coefficient suggests that the variable remains non-significant. A rise in natural gas consumption had a favourable influence on trade openness among oil-producing countries throughout the analysed time period, according to the natural gas price estimator, which also showed a positive coefficient. The natural gas price coefficient also has a p-value that shows the variable is significant at the 1 percent level of significance. Additionally, throughout the period under consideration, the estimate of the internal instrumental variable—more precisely, motor petrol consumption—showed a negative coefficient, suggesting that motor petrol consumption had a negative impact on trade openness among oil-producing countries. As an added bonus, the coefficient's p-value is also statistically significant at the 1 percent level. Table 7 also shows the Wald statistic for the null hypothesis, which states that all coefficients, save the constant, are equal to zero. With a chi-square p-value less than 0.05, we may definitely exclude the null hypothesis that all coefficients are zero, with the exception of the constant.

Both AR(1) and AR(2) have p-values greater than 0.05, according to the Arellano-Bond dynamic panel trade openness model's post-

Table 7. Arellano-Bond Dynamic Panel Estimation to find out impact of Natural Gas Consumption, Natural gas Price and Gasoline Motor Fuel Consumption on Trade Openness (TOP)

Lntop	Coeff.	Std.Error	z	P>|z|
lntop				
L1	0.6192***	0.0608	10.19	0.000
lnngc lnngp lnmgc	-0.0048	0.0323	-0.15	0.883
constant	0.103***	0.0345	2.98	0.003
	-0.1408***	0.0359	-3.93	0.000
	1.8952***	0.3251	5.83	0.000
Wald chi2 = 211.56|Prob > chi2 = 0.0000				

Note 1: (***), (**) and (*) indicates significant at 1%, 5% and 10% level respectively. Note 3: The internal instruments employed are lnngc and lnmgc.
Source: Author's Computation, 2023.

Table 8. Result of Post-estimation tests on Arellano-Bond Dynamic Panel TOP Model

Arellano-Bond test for AR(1) in first differences z [Pr > z]	**Arellano-Bond test for AR(2) in first differences** z [Pr > z]	**Sargan test of overriding restrictions** chi2 [Pr > chi2]	**Hansen test of overriding restrictions** chi2 [Pr > chi2]
-0.35* [0.721]	-0.44 [0.661]	0.27** [0.603]	0.00 [1.000]

Note 1: (***), (**) and (*) indicates significant at 1%, 5% and 10% level respectively. Note 3: The internal instruments employed are ngc and mgc.
Source: Author's Computation, 2023.

estimation diagnostics results (Table 8). This points to the fact that the idiosyncratic error component, which is related at some higher level (namely, second-order), remains unlinked throughout time. Hence, we should not accept the null hypothesis that the trade openness dynamic panel model does not exhibit first-order and second-order serial correlation in the first differences, as demonstrated by the AR(1) test, and higher-order serial correlation in the first differences, as suggested by the AR(2). Table 8's data and the p-value from the Sargan and Hansen test statistic both point to the dynamic panel model's joint validity being a viable null hypothesis to reject. In order to evaluate the effect of natural gas consumption and pricing on trade openness using the Arellano-Bond dynamic estimating approach, the instrument variable may be employed as it is considered real.

5. DISCUSSION OF FINDINGS

The research examined the impact of natural gas use, natural gas pricing, and gasoline motor fuel usage on trade openness in African nations that produce oil. The research revealed that the link between natural gas consumption and trade openness was not statistically significant. However, natural gas pricing had a substantial beneficial influence on trade openness. Conversely, the use of petrol motor fuel had a significant negative effect on trade openness. The observed correlation between natural gas consumption and trade openness contradicted the outcomes of Shahbaz et al. (2014) and Bonsu and Wang [26] who identified a mutual causal link between trade openness and energy consumption. The discrepancy between the upshots of this research and those of Shahbaz et al. (2014) and Bonsu and Wang [26] may be attributed to differences in the data utilised, the number of variables comprised in their models, and the data analysis methodologies used. Furthermore, the upshots of this research about the influence of natural gas prices on trade openness align with the outcomes of Akinwale [27,28], who indicated that an increase in oil prices has a substantial effect on trade openness.

Insufficient ability to turn the raw resource into other economic uses has led to the oil and gas industry being the primary source of export commerce and income for sub-Saharan African nations for many years. For example, natural gas is a significant primary resource for power generation and the petrochemical sectors. However, the majority of natural gas producing nations in Africa have poor levels of electricity supply and consumption. Additionally, the production of the industrial sector continues at a low level, resulting in a significant degree of unemployment and poverty in the area. Therefore, determining the precise impact of the oil and gas industry on Africa's economy is very challenging, despite the significant exportation of natural gas and crude oil over the years.

6. CONCLUSION

The research investigated the impact of natural gas use on promoting commerce among the leading gas-producing nations in Africa. The research used the panel ARDL approach and discovered that an escalation in the price of natural gas contributes to the enhancement of commerce and economic development in the leading gas-producing nations in Africa. As the price rises, there is a corresponding increase in commerce, particularly in exports, which leads to a growth in monetary terms. Additionally, the energy industry plays a significant role in contributing to the overall economic development. Trade openness is enhanced by the combination of trade and economic development, with the price of natural gas playing a crucial role in this improvement. The trade facilitation in the chosen gas-producing African nations was greatly hindered by the high natural gas prices and increased demand of gasoline motor fuel. In congruent with these upshots, it is recommended to liberalise the oil and gas sector in nations that produce gas. This would encourage competition, stabilise prices, strengthen gas infrastructure, and boost trade and development in gas-producing nations in the African sub-region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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