ENERGY DIVERSIFICATION IN AFRICA: THE PANACEA FOR SOLVING THE ENERGY PARADOX

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ABSTRACT
The paper empirically examined energy diversification in Africa. Although Africa is endowed with abundant energy resources, their accessibility, efficiency and affordability are far-fetched. This is paradoxical, a situation of scarcity in the midst of plenty. A cross sectional panel data sourced from World Development Indicators (WDI), International Monetary Bank (IMF) and World Bank were used to examine five selected African countries, one from each region of the continent. In this paper, Gross Domestic Product (GDP) which represents economic growth stood as proxy for Energy diversification – the dependent variable while Renewable Energy (RE), Nonrenewable Energy (NRE), Gross National Expenditure (GNE), Trade Openness (TOP) and Population (POP) were the explanatory variables. The panel estimation techniques employed in this study were the fixed effect model and the Random effect model and thereafter, the Hausman test was performed to ascertain whether to adopt the fixed effect model or the Random effect model. The Hausman test confirmed that the fixed effect model is more preferable. Some of the major findings of the study include that RE & NRE exhibited both positive but insignificant relationship with economic growth while GNE & TOP were both positive and significant. Population however impacted negatively and insignificantly to economic growth in the selected countries. The paper recommended that the government should increase the availability and affordability of abundant RE resources through increased energy diversification.

Keywords: Economic Growth, Renewable Resources, Nonrenewable Resources, Energy diversification

JEL CLASSIFICATION: 04, Q20, Q30, Q49.

1. INTRODUCTION

Energy is pivotal to the growth of any economy - both developed and developing economies. In consideration of the vital place of energy in global developmental process, Sustainable Development Goal (SDG) number 7 calls for "access to affordable, reliable, sustainable and modern energy for all by the year 2030". This clarion call for cleaner energy to reduce Green House Gas (GHG) emissions is vigorously being pursued by many advanced nations. With few years to the deadline, most African countries are still deeply engaged in activities that result to high production of chlorofluorocarbon gases. Apart from meeting the United Nation's global declaration, Africa is still regarded as energy dependent due to wastage. Nigeria, for instance, one of the countries in the continent that is abundantly endowed with energy resources is the most notorious country in the world for oil spills. From statistics, the country is losing roughly 400,000 barrels per day in oil spills followed by Mexico that loses only 5,000 to 10,000 barrels per day thus creating a staggering difference of about 3,900% (Abubakar, 2021).

Apart from the health implications and the damage to the environment, these oil spills can be converted to useful materials that add value to economic well-being of the country if there is an efficient diversification of the energy. Ogungbenle (2021) succinctly pointed out that apart from increase in foreign exchange earnings, other benefits of energy includes transfer of technology through exploration, production and marketing, employment generation, infrastructure and socio-economic activities. Energy diversification is the introduction of different energy sources into the energy generation mix and increasing the share of energy generated from each source to avoid sole dependent on a single energy source (Stirling 2010). Diversification of energy serves as a buffer against energy shocks and ensures that the country becomes easily adaptable in the face of uncertainties. Knowledge of some concepts is basic for clear understanding of energy diversification. One of such is energy security which refers to the availability, accessibility, affordability and reliability of energy. Another is energy mix which refers to a combination of different energy sources used to meet a country's total energy consumption.

According to Worldbank (2024), global shocks such as the COVID-19 pandemic, the war in Ukraine and conflict in the Middle East have further slowed the progress towards achieving the universal access to affordable, reliable sustainable and modern energy by 2030. The report further stated that developing countries face the highest burdens due to limited capacity to mitigate energy price volatility leading to energy rationing in some countries and escalating poverty (worldbank.org/energy).

The global economy is geometrically growing ahead of the pace with which the earth replenishes itself. World population explosion and excessive energy demands especially in emerging economies (which includes many African countries) pose great challenge to economic growth and the environment (Panshak et al, 2021). The economic landscape of many African countries is not encouraging. For instance, the monolithic nature of Nigerian economy, over dependence on crude oil and lack of control over the global crude oil price in the international market has led the country to a spiral of economic challenges that impede economic growth (Adamu & Usman 2022). In a similar report by the Worldbank (2024), due to weakened economic fundamentals driven by monetary and exchange rate policy distortions, low oil production and fuel subsidy removal, the country's inflation has reached a 24-year high of 31.7% in February 2024 pushing millions of Nigerians into poverty (worldbank .org>country). The thinking in the minds of many Nigerians is that if the country had diversified its energy resources away from petroleum, the removal of fuel subsidy would not have placed the citizens in this present harsh condition.

However, there have been some policy initiatives both at the continental and national levels to ameliorate the energy problems. In Nigeria for instance, to cushion the effects of fuel subsidy removal and the implementation of foreign exchange market reforms, government announced the implementation of direct cash transfers, distribution of foodstuffs such as rice and provision of additional public transport services and wage increase for some public-sector employees. These measures are widely felt to be insufficient to address the impacts of the subsidy removal because it lacks social impact assessment and the principles of distributive justice which should include the welfare of the poor and the less privileged.

However, these reforms, notably allowing market-reflective pricing and eliminating the multiple FX windows, the government projected to achieve estimated fiscal gains of about N3.9 trillion in 2023 which if sustained would lift the country's economic trajectory and protect the poor and the vulnerable (worldbank.org/projects). Also at continental level, there were series of seminars/workshops organized by notable organizations in 2023 to advance the energy sector in Africa. These organizations include the Windaba, a wind energy stakeholder that showcased the impact, innovations and influence of wind energy in Africa and beyond; the

Global Energy & Infrastructure, the Green Energy Africa Summit and the Africa Investment Exchange: Power and Infrastructure (standardbank.com).

Most African countries are blessed with abundant renewable and non-renewable energy resources, yet, the continent remains the least developed in the committee of nations with respect to energy accessibility, efficiency and affordability. This is paradoxical, a continent experiencing energy poverty in the midst of plenty. Due to infrastructural, human and technological deficiencies, most of these energy resources are underutilized or misutilized and therefore are being exported to more developed countries of America, Europe and Asia as primary products at highly reduced prices. These products when processed abroad are imported as finished products at very exorbitant prices thereby creating huge drain on the economy. For instance, oil imports in Nigeria in 2021 amounted to 1.04 billion US dollars (CBN 2022).

In 2021, Tunisia spent 941 million US dollars in importation of petroleum and gas while Congo Democratic Republic importation of refined petroleum stood at 406 million US dollars. Burundi in 2021 with its meager resources spent 160 million US dollars in importation of refined petroleum products (data.world bank.org2022). In 2021, South Africa spent 7.85 billion US dollars in importation of refined petroleum, becoming the 26th largest importer of refined petroleum in the world (Oec.world.2022). The statistics dwelt on the five selected African countries covered in this study, and it serves as an eye opener of the huge staggering scarce foreign exchange which African countries spent on importation of petroleum products. Regrettably, most of these countries are heavily endowed with energy resources. For instance, Nigeria is abundantly endowed with coal, petroleum, reserves, natural gas, peat, hydropower, solar, biomass, and wind as major energy resources as there are still many more that are not mentioned here. Tunisia has high deposits of phosphate, Zinc, lead, barite, iron, petroleum and hydropower.

Congo Democratic Republic is blessed with oil and gas, uranium and other renewable energy resources such as solar, wind, and geothermal. Also, the country has diamond, gold, copper and is the highest producer of cobalt in the world, a key component used in battery production. Burundi's energy resources include hydropower, wind, solar, geothermal and biomass. Burundi has the second largest coltan reserve in East African region and the 6th world nickel reserve. Yet, the country's GDP per capital stood as low as 262.18 US dollars in 2022 (data.worldbank.org). South Africa has coal as its major energy resources and the 6th coal producer in the world after China, USA, India, Russia and Australia. Other energy resources of the country include uranium, crude oil and gas though at very limited quantity. Apart from individual countries' endowment, the location of Africa in the tropics is an added advantage for receiving long hours of sunshine that are readily convertible into energy purposes through solar radiation. Also, the continent is surrounded by the Mediterranean Sea, the Red Sea, the Indian Ocean and the Atlantic ocean providing the coastal areas of the Western, Southern and Northern regions with abundant wind that are potential sources of energy to generate electricity. Diversifying the energy resources in Africa especially through investments in renewable energies will increase energy access, create employment, engender clean energy transitions and ensure energy security (Akrofi, 2021).

Regrettably, Africa has not received much scholarly studies with respect to energy diversification unlike European and Asian countries, some of which include: Gorbet al (2020), Allam (2022), Harrington et al (2020), Kireyev (2020), Vivoda (2019) and Triguero –Ruiz (2023). The few studies on energy diversification in Africa include Pistelli (2020) and Akrofi (2020).

The primary objective of this paper is to empirically examine factors which significantly contribute to energy diversification in Africa. This is a topical issue and germane to African development especially in the present global economic challenges with many African

countries' over dependence on single primary energy product in the midst of abundant renewable and non-renewable energy resources. Our study contributes to the extant literature by empirically investigating the energy diversification in Africa. The specific contribution of the paper can be viewed from these perspectives: variables used, scope and method employed. On variable perspective, the explanatory variables consists of renewable and nonrenewable energy resources, gross national expenditure, population and trade openness. Previous similar studies for instance Yilanci et al (2021), Akrofi (2021), Lee & Ho (2022) and Gorb et al (2020) did not incorporate these variables as outlined in our model. The inclusion of some of these variables for example population (a continent with rapid growing population) and (a continent with many inhibiting factors to trade openness) are very imperative in gaining a proper insight into the energy diversification in Africa. The study covered the duration from 1986 to 2022, a very wide period that is expected to give a reliable result. Also, five countries, one from each region in the continent, three of which are those with high GDP while the remaining two are with low GDP were selected. The aim was to ascertain whether energy diversification is determined by the amount of income possessed by a nation or whether there are other variables. To the best of our knowledge, these specific novel contributions are absent in previous studies. Hence, this paper is directed to fill this gap.

The rest of paper is structured as follows: section 2 centered on theoretical and empirical literature review. Section 3 presents the methodology, while section 4 dwelt on analysis and discussion of findings, section 5 centered on the conclusion and policy recommendations.

2. LITERATURE REVIEW

2.1 Theoretical Literature Review

The theoretical underpin of this paper hinges on the Environmental Kuznets Curve (EKC) theory. This is because energy, climate and economic growth are intrinsically linked. This theory was first propounded by Simon Kuznets in 1955 showing the relationship between income per capital and income inequality. However, the theory has gone through several revisions relating it to income and environmental pollution as empirically tested and demonstrated the existence of the inverted –U shape of the Environmental Kuznets curve. (Grossman & Krueger 1991). The implication of the EKC suggests that the quality of the environment decays at the initial or early stage of growth of the economy because of the massive usage of conventional energy sources such as fossils. At a later stage of economic development, the quality of the environment improves (Panshak et al 2021). Both Environmental Economists and Ecologists have emphasized that the environmental has limited waste processing power and that environmental pollution occurs when such wastes are above its assimilation capacity (Mitic et al 2019).

Another relevant theory reviewed in this paper is the David Ricardo's theory of Comparative Advantage in which he argued that regions/countries have different factor endowment in terms of natural abilities and resource endowments, that each region/country should specialize in and export those products which use intensively the factors of production in which it is most endowed (Ricardo 1817). Going by this theory and under certain assumptions, if each region/country specializes in production of energy resources where it has comparative advantage, total output and economic welfare will increase and to a large extent there is diversification of the energy resources in the economy. In support of this view, the World Trade Organization (WTO) emphasizes that more and more products made in the world and participation in global value chains has the potential to offer developing countries an opportunity to increase their growth rates (Ravenhill, 2014). The view advocated by David Ricardo in his theory of comparative advantage has heavily been criticized. One of such critics include Siddiqui (2018) who argued that the theory locks less developed countries (LDCs) into relation of unequal exchange with developed countries (DC) where the LDCs perpetually

continue to produce and export their raw materials at cheap prices while the DC focus on the production of manufactured goods that are highly priced.

2.2 Empirical Literature

Moshsin et al (2021) in their study assessed the impact of transition from non-renewable to renewable energy consumption on economic growth-environmental nexus from developing Asian countries. The result of their study was in consonance with the growth hypothesis and it was positive. Onyechi, & Ejiofor (2021). Decarbonizing Nigeria's energy mix: The role of renewable energy consumption. Their findings showed a positive relationship between trade openness, carbon emission from non-renewable sources and renewable energy consumption.

Okumus et al (2021) carried out a study on renewable, non-renewable energy consumption and economic growth nexus in G7. Fresh evidence from Cross Sectional Augmented Auto-regressive Distributed Light (CS-ARDL).The result revealed that the coefficient of REN & NREN consumption are positive and statistically significant both in short-run and long run. The panel bootstrap to causality analysis revealed that the growth hypothesis is valid in REN and NREN only for Canada but at variance for other countries. Gorb et al (2020) examined the pathways for diversifying energy supply in rural Ukraine and in their findings, they identified biomass as the most promising renewable source for rural areas. Allam (2022) in his study titled "Towards a sustainable energy pathway for Bangladash", identified energy diversification as a strategy for sustainability and resilience in mega cities.

Lee & Ho (2022) studied the impacts of export diversification on energy intensity, renewable energy and waste energy in 121 countries and also went further to investigate whether environmental regulations have any impact. They found that export diversification leads to more energy intensity but less consumed renewable and waste energy. Li et al (2023), investigated the impact of energy affordability on decision-making of rural households in ecologically fragile areas of North West China. Their findings revealed that energy affordability had heterogeneous effects and that these effects/affected various groups differently.

Gacitua et al (2018), examined a comprehensive review on expansion planning: models and tools for energy policy analysis. Their findings revealed that energy systems are quickly evolving through the development of new technologies and the emergence of new operational market design paradigms due to global push for sustainability particularly towards the renewable energy integration. Fasoye & Olayiwola (2023) in their study of energy efficiency measures and private-households in Nigeria, revealed that with Nigeria's rapid growing population, energy efficiency would contribute to the overall resilience of the energy sector and bring about country's sustainable development. Nwatoh, L.S. (2021). Testing the long relationship between natural gas utilization and economic activities in Nigeria. The finding revealed that natural gas utilization impacts positively to economic growth in Nigeria.

3. METHODOLOGY

3.1 Theoretical Framework

The theoretical framework of this study leans on the Environmental Kuznets Curve model as specified by a similar study carried out by Komolafe (2013). The EKC theory has clearly been explained in the theoretical literature review. In this paper, a simple modified version of the EKC model is adopted and our model specification is stated below:

3.2 Model Specification

The model specification for the study is expressed as:

GDP = Renewable Energy Consumption+ Non-renewable Energy Consumption+ Gross National Expenditure + Trade Openness + Population

$$GDP_{it} = \beta_0 + \beta_1 RE_{it} + \beta_2 NRE_{it} + \beta_3 GNE_{it} + \beta_4 TOP_{it} + \beta_5 POP_{it} + \epsilon_{it}$$

As a stand-in for energy diversification, the GDP was calculated using 2010 NGN prices that were constant.

Energy usage from all renewable resources is included in the Renewable Energy Consumption (RE) indicator which covers hydro, solid bio-fuels, wind, sun, liquid biofuels, biogas, geothermal, marine, and waste energy. Following the industrial revolution, energy use and other crucial inputs like labor and capital became intricately linked to growth.

Non-Renewable Energy Consumption (NRE): The total amount of energy used by a business, including energy from non-renewable sources like fossil fuels and energy that is purchased, is known as non-renewable energy consumption.

Gross National Expenditure (GNE): The total of final consumer spending (household; formerly private consumption), final consumer spending (general government; formerly general government consumption), and gross capital creation (formerly gross domestic investment) is known as gross national expenditure.

Trade Openness (TOP): is a metric used to assess how much a nation participates in the world trade system. The ratio of gross domestic product (GDP) to the total of imports and exports is commonly used to assess trade openness.

Population (POP): This is the total number of inhabitants, irrespective of citizenship or legal status, with the exception of refugees who have not established permanent residence in the nation of asylum and are typically counted as citizens of their home country.

Sources of Data

A cross sectional panel data sourced from World Development Indicators (WDI), International Monetary Bank (IMF) and World Bank were used in this study.

4. RESULTS AND DISCUSSION OF FINDINGS

Panel Unit Root

Since the existence of unit root test can lead to spurious regression, it is essential to ensure that the series are stationary to guard against this.

Table 1: Summary of Panel Unit Root

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-5.35192	0.0000	5	175
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-5.60416	0.0000	5	175
ADF - Fisher Chi-square	50.9104	0.0000	5	175
PP - Fisher Chi-square	91.7581	0.0000	5	180

** Probabilities for Fisher tests are computed using an asymptotic Chi

-square distribution. All other tests assume asymptotic normality.

Source: Authors' Computation

The result of the panel unit root presented in Table 1 shows that the variables are stationary at first difference based on the fact that all the p values are less than 0.05. It is therefore concluded that the variables are stationary and the null hypothesis is rejected.

Table 2: Correlation Analysis

	GDP	RE	NRE	GNE	TOP	POP
GDP	1.0000					
RE	-0.2512	1.0000				
NRE	-0.2348	0.2832	1.0000			
GNE	0.9874	-0.2856	-0.2090	1.0000		
TOP	-0.1669	-0.5623	-0.3797	-0.1423	1.0000	
POP	0.6208	0.1945	-0.2687	0.5832	-0.2652	1.0000

Source: Authors' Computation

From the result in Table 2, the coefficient values for all the variables reveal that the model is well specified since the values are below the threshold of 0.80. The decision rule is that if the values in absolute term is greater than 0.80, there is multicollinearity in the model. Otherwise, there is no multicollinearity. In summary therefore, since the values are less than 0.80 in absolute term, the model is well specified and there is no multicollinearity.

Table 3: Fixed Effect Model

R-squared: F(5, 180) = 837.72 Within = 0.9588 Between = 0.9807 Overall = 0.9451 Corr (u_i, xb) = 0.5808						
GDP	Coefficient	Std.Error	t	P>|t|	95% conf.	interval
RE	.5369938	.7116551	0.75	0.451	-.867266	1.941254
NRE	2.023332	1.847146	1.10	0.275	-1.621514	5.668178
GNE	.9860755	.0255046	38.66	0.000	.935749	1.036402
TOP	.3540395	.1482852	2.39	0.018	.0614387	.6466404
POP	-17.06338	10.56835	-1.61	0.108	-37.91717	3.790415
_cons	247.0623	162.1202	1.52	0.129	-72.83836	566.9629
Sigma_u	39.004407					
Sigma_e	19.80958					
rho	.7949488 (fraction of variance due to u_i					
F test that all u_i=0: F(4, 180) = 9.29					Prob > F = 0.0000	

Source: Authors' Computation

The result of the fixed effect model in Table 3 shows that renewable and non-renewable energy sources have positive but insignificant effect on economic growth in the selected countries.

The coefficient values are 0.53 and 2.02 respectively, which indicate that and increase in renewable and non-renewable energy will increase economic growth in these countries. Renewable and non-renewable energy can contribute to economic growth and a way of diversifying the energy sources, in the sense that businesses will have more access to their consumption which will in turn aid production of goods and services. The finding however conforms to the a priori expectation because it is expected that, irrespective of the energy sources, it must stimulate production of goods. This is contrary to the findings of Okumus et al. (2021), and Razmi et al (2020) which revealed that renewable and non-renewable energy consumption have negative effect on economic growth. Our finding is however, in consonance with similar scholarly studies such as Sarkodie et al (2020), Venkatraja (2019) and Lazar et al (2023)

Gross national expenditure (GNE) has a positive but significant effect on economic growth, with the coefficient value of 0.98607. The implication is that one percent increase in GNE on average will increase economic growth by 0.99%.This is so because spending on critical developmental projects will help provide conducive environment for investment to thrive, which tends to enhance (economic growth) energy diversification. This finding also conforms to the a priori expectation. Trade openness also exerts positive significant impact on economic growth of the countries selected. The more an economy is opened to trade, the more investments that would stimulate economic growth in Africa. Our findings on trade openness conformed to studies by Odhiambo (2021) and Gonese et al (2023). In their studies however, they pointed out for the trade openness to impact positively on economic growth it should be directed towards boosting of exports and not imports.

Population however shows a negative and insignificant effect on economic growth. The coefficient value is -17,0633 which implies that on average, one percent increase in population will result in a decline of about 17% in economic growth. This may be connected to the fact that generation of the renewable and non-renewable energy in these countries is not even adequate for the population now. So, any attempt to increase the population from the current figure, will affect the consumption of energy in the selected African countries. Nigeria is a good example of this scenario because at the moment, the generation of energy for consumption is low and it usually causes unstable power supply. The inadequate access to these energy sources for consumption most times results into high cost of production which causes the prices of goods and services to increase, since businesses have to depend on alternative source of energy such as diesel. The renewable energy sources that can give greener economy, low emissions than most non-renewable energy source is more expensive even for common man to access. Going by the p values, only GNE and TOP are statistically significant with economic growth because the p values are lower than 5%.

The R^2 of 0.945 reveals that the variations in economic growth are highly explained by renewable energy, non-renewable energy, gross national expenditure, population and trade openness. Similarly, the probability value of F-statistic which is 0.0000 shows the variables are jointly statistically significant since the value is lower than the critical value at 5 percent level of significance.

Table 4: Random Effect Model

R-squared:	Wald chi 2(5) = 8620.29
Within = 0.9554	Prob > chi2 = 0.0000
Between = 0.9972	
Overall = 0.9791	

Corr (u_i, x) = assumed						
GDP	Coefficient	Std.Error	z	P>|z|	95% conf.	interval
RE	.0063336	.0612457	0.10	0.918	-.1137058	.1263729
NRE	-2.46872	.8818068	-2.80	0.005	-4.19703	-.7404106
GNE	.9764975	.0166935	58.50	0.000	.9437788	1.009216
TOP	-.1905657	.0907756	-2.10	0.036	-.3684826	-.0126487
POP	-90.7771	2.061533	3.22	0.001	2.587694	10.66875
_cons	-90.7771	34.74616	-2.61	0.009	-158.8783	-22.67589
Sigma_u	0					
Sigma_e	19.80958					
rho	0 (fraction of variance due to u_i					

Source: Authors' Computation

The result of random effect model presented in Table 4 reveals that renewable energy (RE) has positive impact while non-renewable (NRE) energy has negative effect. The coefficients indicate that one percent increase in RE will increase economic growth by 0.006% while an increase in NRE will decrease economic growth by 2.47%. The decline that may result from the use of NRE may be because many economies are trying to diversify into using cleaner energy sources like solar due to greenhouse gas emissions that are caused by NRE. Our findings disagreed with similar studies carried out by Ikhide (2021) in which his result revealed that fossil fuel energy consumption (NRE) positively contributes to economic growth whereas renewable energy consumption has a negative impact on Nigeria economic growth. Trade openness also has negative effect on GDP. This may be because of many unfavourable trade policies which scare investors away. When investors do not invest in a country, there will be high unemployment, inflation and low energy diversification quest (economic growth). This finding is in consonance with similar studies by Ugwoke et al (2016) that found trade openness to impact negatively to economic growth in Nigeria. However, gross national expenditure and population have positive effect on economic growth. This implies that one percent increase in gross national expenditure and population will result in increased economic growth. From the random effect model, only RE is not statistically significant, but other variables (NRE, GNE, TOP, POP) are statistically significant at 5 percent. Our finding is in consonance with similar studies by Gozagor & Paramti (2022) in which they found that the energy diversification has a significance positive impact on economic growth at the long run.

Table 5: Hausman Test

	(b) Fe	(B) re	(b-B) Difference	Sqrt (diag(V_b-V_B)) Std.error
RE	.5369938	.0063336	.5306602	.7090148
NRE	2.023332	-2.46872	4.492052	1.623073
GNE	.9860755	.9764975	.0095781	.0192824
TOP	.3540395	-.1905657	.5446052	.1175253
POP	-17.06338	6.628223	-23.6916	10.36533

Source: Authors' Computation

The Hausman test is used to determine which model is more preferable between the fixed and random effect models. To determine this, if the probability of Hausman test must be lower than 5 percent, the fixed effect is preferable but it is higher, then random effect model is preferable. From the result presented in Table 5, it is clearly seen that fixed effect model is the appropriate model to be adopted in this study, owing to the fact that the probability value of chi2 (0.0000) is lower than 5 percent. The fixed effect model removes the influence of unobserved factors hence enabling a more accurate estimation of the effects of interest and also be in a position to uncover the unique impact of different variables of interest.

Table 5: Concentration Index for RE

Index:	No. of Obs	Index Value	Std. error	p-value
Modified Gini	190	.44286866	.01519092	0.0000

Source: Authors' Computation

The provided concentration index value of 0.44286866 for renewable energy consumption suggests a moderate level of inequality in how renewable energy resources are distributed between countries with high GDP and those with low GDP. This indicates that there may be disparities in the utilization of renewable energy among countries, with some countries having a disproportionately higher share of renewable energy consumption compared to others. Purwanto et al (2021) in their study revealed that inflation, poverty and debts are the main culprits for increased consumption of non-renewable energy both in the short & long-run, implying that countries with low GDP are likely to consume more of non-renewable energy resources. Asogwa et al (2018) in their studies had a similar result but went further to identify population density as the crucial factor influencing the regeneration of renewable energy in Sub-Saharan Africa. The standard error of 0.01519092 reflects the precision of this estimate, implying a relatively confident assessment of the observed inequality. Additionally, the low p-value of 0.0000 indicates that the observed level of inequality is highly statistically significant, reinforcing the notion that these disparities are unlikely to be due to random chance. This underscores the importance of addressing the observed inequalities in renewable energy consumption between high and low GDP countries to promote more equitable and sustainable energy transitions on a global scale.

Table 6: Concentration Index for NRE

Index:	No. of Obs	Index Value	Std. error	p-value
Modified Gini	190	.49545124	.02099408	0.0000

Source: Authors' Computation

The concentration index (or modified Gini coefficient) for non-renewable energy consumption between countries with high and low GDP is estimated at 0.49545124. This signifies a notable disparity in the distribution of non-renewable energy usage across these nations, with certain countries exhibiting significantly higher consumption levels compared to others. The relatively precise estimate, indicated by the standard error of 0.02099408, enhances the credibility of the observed inequality. Furthermore, the exceptionally low p-value of 0.0000 underscores the statistical significance of the finding, suggesting that the observed discrepancies in non-renewable energy consumption between high and low GDP countries are highly improbable to have arisen randomly. This emphasizes the critical need to address these imbalances to foster more equitable and sustainable energy consumption practices, particularly among nations with differing economic status.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study examines how energy diversification can ensure access to cleaner energy in Africa. The study covers the period between 1986 and 2022, using fixed effect model. The concentration index which fulfills the cardinality property was also adopted in this study. Energy diversification from the non-renewable to renewable energy source has over the years been the global agitation due to the effect of non-renewable energy on climate change. From the result of fixed effect model in this study, both the renewable and non-renewable energy sources are positive and statistically insignificant. Similarly, gross national expenditure and trade openness have positive and significant effect on energy diversification. However, population's effect on energy diversification was negative and statistically insignificant. Based on these findings, the study suggests that;

i. Government of these African countries must invest heavily on renewable energy in order to diversify the use of energy from non-renewable energy to renewable energy owing to the effect of the non-renewable energy on global warming. The renewable energy source should be made easily affordable and accessible for the masses to consume as well.
ii. Since trade openness has positive and significant effect on energy diversification, government should ensure that trade policies are more favourable to investors so as to attract more foreign and domestic investors who may want to invest in energy sector as a way of diversifying the energy usage from the current sources of energy used by most African countries.
iii. Population growth has negative and insignificant effect on energy diversification. This is a clear indication that in spite of the large population of most African countries, and the abundant energy resources, these remain unavailable to the citizens. It is therefore recommended that government should generate more renewable energy sources which the continent is heavily endowed with.

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