DECOUPLING GROWTH AND EMISSIONS: ECONOMETRIC EVIDENCE FROM SELECTED AFRICAN ECONOMIES

K. M. NOOR-E-ZANNAT NADI
South Asian Institute of Policy and Governance, North South University, Bangladesh
Email: noor.nadi@northsouth.edu
Phone: +8801617534353

MOHIMA CHOWDHURY
Department of Economics, University of Dhaka, Bangladesh.
E-mail: s-2020512503@econ.du.ac.bd
Phone: +880 1999101159

NAZMUL ALAM ARNOB
Department of Economics, University of Dhaka, Bangladesh.
Email: s-2020217736@econ.du.ac.bd
Phone: +880 1781817732

MD SHIYAN SADIK
Department of Environmental Science and Management, North South University, Bangladesh
Email: shiyan.sadik@northsouth.edu
Phone: +880 1776197971

ABSTRACT

The nexus between economic growth, energy consumption, and climate change aligned with different emission levels has been a growing contention among the stakeholders. The narrative of striking a balance between economy, climate, and resource management is one of the primary fundamentals of recent Sustainable development goals. African nations are not only geographically important but also economically significant which is mostly ignored in most research. This study employed the autoregressive distributed lag (ARDL) approach as it explains how economic variables change over time. To examine the overall impact of energy consumption (per capita), renewable energy consumption (per capita), and CO2 emissions on GDP, three African nations—Nigeria, South Africa, and Morocco—have been selected. . According to this study, renewable energy may impede economic progress. On the other hand, over time, renewable energy sources do hurt CO2 emissions but a positive effect on measures of economic growth like GDP per capita. African nations have the option to use renewable energy sources, which can lessen environmental harm and promote general economic expansion. This study can help emerging nations find strategies to attain sustainable development without reverting to the carbon-intensive models of the past. Policymakers can use this information to determine which economic sectors use the most energy and to evaluate the effects of switching to low-carbon alternatives. This study also impacts the security of the energy supply because reliance on renewable energy sources lessens reliance on finite and unstable fossil fuel supplies. Additionally, it advocates for the implementation of financial incentives that encourage innovation and private investment in sustainable practices, such as carbon taxes and green financing.

Keywords: Economic Growth, Energy Consumption, Renewable Energy, CO2 Emissions, Sustainable Development
JEL Classification: O13, Q43, Q56

1. INTRODUCTION

Africa is a country of rich natural resources. The continent is the source of 30% of the world's minerals, such as gold, diamond, iron, cobalt, copper, uranium etc. Africa also contributes to the global gas, petroleum, and oil supply. According to Singh (2024), abundant natural resources create economic opportunities for African countries to prosper. Despite the colonial past, African countries utilize their human and natural resources to achieve their full potential. In general, economically enriched countries use more energy compared to others. In Africa, most of these energies are mainly fossil fuels. While higher energy consumption allows the counties to achieve higher GDP growth, this often leads to increased CO2 emissions. Hence, industrialization has a major impact on economic production and a negative impact on the environment. However, the worldwide concern for a better environment for future generations is now inspiring African countries to strike a balance between growth and sustainability while analyzing the process of renewable energy to reduce emissions and ensure long-term prosperity.

Countries such as Nigeria, Morocco and South Africa have the most dynamic economies in Africa. Because of their heavy reliance on fossil fuels, South Africa and Nigeria can be considered major CO2 emitters and energy users. Likewise, South Africa, the most industrialized country on the continent, has seen a significant increase in energy consumption due to its increasing mining and processing industries. According to the IEA (International Energy Agency), this contributes to more than 90% of its energy demand. On the other hand, Morocco invests in renewable energy, presenting an insightful case study on low-carbon growth.

Aliyu, Modu, and Tan (2017) argue that Africa has abundant energy sources, especially renewable energy. Yet, it is facing a severe crisis due to not using renewable energy sources or suitable technology and its overdependence on fossil wood. According to Wesseh and Lin (2018), the state of technological progress usually depends on its input, which is highest at less than 9%. This indicates a huge potential to reduce CO2 emissions that can be generated by innovating different energy technologies.

In-depth research on the relationship between GDP, energy consumption, and CO2 emissions is essential as these factors form the basis of the current economy and address the global sustainable challenges. Gross domestic product (GDP) is widely used as an indicator of economic activity. Historically, economic growth has been accompanied by increasing demand for energy. This growing demand for energy is particularly satisfied with fossil fuels such as coal, oil and natural gas, which cause high CO2 emissions. These emissions are the main drivers of climate change, leading to severe environmental, economic and social impacts, such as global temperature increases, extreme weather conditions and biodiversity loss. Understanding the complex link between GDP, energy consumption, and CO2 emissions is crucial to address the dual challenges of stimulating economic growth while reducing environmental damage. For developing countries, this study can identify ways to achieve sustainable development without repeating the carbon-intensive models of the past. In developed countries with higher emissions per capita, such studies may reveal strategies to separate economic growth from environmental degradation. These findings are significant for the global efforts to achieve climate objectives, such as those set out in the Paris Agreement, which aims to limit global temperature increases to below two degrees Celsius compared to pre-industrial levels. This research can help policymakers identify the most energy-intensive sectors of the economy and assess the impact of the transition to low-carbon alternatives. This study also affects the security of energy supply, as dependence on renewable energy sources reduces dependence on limited and geopolitical volatile fossil fuel reserves. It furthermore supports the introduction of economic incentives such as carbon prices and green financing that stimulate innovation and private investment in sustainable practices. By examining how economic efforts can be balanced with environmental management, this study provides the basis for changes that benefit current and future generations.

The intertwined relationships around economic growth with energy consumption and CO_2 emissions, portrayed in Nigeria, South Africa, and Morocco, have complicated working mechanisms based on the types of their economic structures, energy policies, and commitments to sustainability. Nigeria is too reliant on hydrocarbons, fossil fuels, and gas flaring, which induce rising CO_2 emissions, given that adopting renewable energy is moderate. With the growing economy and increasing energy demands, emissions will be further caused by continued dependence on nonrenewable energy source options. Most industrialized South African countries still have the double-edged sword of economic growth versus high emissions from coal-based energy production, leaving South Africa transitioning into renewables and gaining momentum. It meets the goal of augmenting its income base while lowering the carbon intensity of its economy. Solar and wind: the new green growth-prevention investments for Morocco. All these differences speak for themselves; they speak differently and face various challenges in balancing the countries' economic development and environmental sustainability.

These new investments in solar and wind energy will propel Morocco's green growth in the same well-known direction—always broadening the income base while reducing the economy's carbon intensity. These differences highlight countries' various approaches and challenges in balancing economic development and environmental sustainability.

The research was fueled by the most pressing need to address these issues under contexts wherein economic growth has always gone hand in hand with heightened pressure on the environment. Research has also revealed impact differentiation depending on renewable or nonrenewable electricity sources and some knowledge gaps in the strategies for sustainable growth and carbon reduction. The results will be useful for identifying instruments for policy towards low-carbon economic growth, with local needs for energy kept in mind and international obligations for taking climate action.

In this research, we chose three countries- Nigeria, South Africa, and Morocco from the African continent to see the overall effect of energy consumption (per capita), renewable energy consumption (per capita), and Co2 emissions on the GDP of each country. These three countries are among Africa's top 10 wealthiest countries and the emitters of the most greenhouse gases. The expected outcome is that GDP growth will increase with more energy consumption and CO2 emissions. This study employed the autoregressive distributed lag (ARDL) approach to examine the overall impact of energy consumption (per capita), renewable energy consumption (per capita), and CO2 emissions on GDP in three African nations—Nigeria, South Africa, and Morocco. According to this study, renewable energy may impede economic progress. On the other hand, over time, renewable energy sources hurt CO2 emissions but have a positive effect on measures of economic growth like GDP per capita. African nations can use renewable energy sources to lessen environmental harm and promote general economic expansion.

2. LITERATURE REVIEW

Khan, Khan, and Rehan (2020) have shown the relationship between Pakistan's energy consumption, economic growth, and CO2 emissions. According to their findings, CO2 emissions are significantly increased by non-renewable energy sources, especially coal, with a 1% increase in coal consumption translates into a 6.7% increase in emissions. Economic growth and emissions are also strongly correlated; for example, a 1% increase in GDP per capita results in a 1.03% increase in CO_2 emissions. They saw a long-run relationship among the variables through the ARDL (Auto-Regressive Distributed Lag).

Ali, Gong, Ali, Wu, and Yao (2020) have shown the relationship between economic development, fossil energy consumption, inward FDI, and CO_2 emissions in Pakistan. It illustrates the Environmental Kuznets Curve (EKC), which shows that emissions increase with expansion before declining beyond a certain point. Fossil fuels and FDI significantly increase carbon emissions. The author suggested eco-friendly technology, renewable energy adoption and sustainable FDI for growth. They also suggested mitigating the environmental harm for the growth. The inverted U-shaped association between economic development and carbon dioxide emissions has been validated by the outcomes of both short- and long-term dynamics.

The study by Osobajo, Otitoju, Otitoju, and Oke (2020) reveals that energy consumption and economic growth significantly increase CO_2 emissions, with population and capital stock also contributing. Energy consumption and economic growth have long-term effects. Granger causality tests show unidirectional relationships between energy use and bidirectional relationships between economic growth and CO_2 emissions. The findings highlight the necessity of international policies supporting energy efficiency, renewable energy, and climate finance to shift to a low-carbon economy without impeding economic growth.

A study by Kivyiro and Arminen (2014) examines how energy consumption, economic growth, CO_2 emissions and foreign money are connected in about six countries in sub-Saharan Africa. Co-integration is demonstrated with Granger causality analysis and the ARL model in all countries. Valid is the ecological Kuznets curve (ETC) hypothesis only for the Democratic Republic of Congo, Kenya and Zimbabwe. The FDI influences CO_2 emissions; in South Africa and the Democratic Republic of Congo, it is falling, but in Kenya and Zimbabwe, it is rising. Countries have very different relationships, which means making plans for each individual. This paper has used MM-PVAR models to see the relationship between renewable energy, CO_2 production, economic growth and good institutions. Acheampong, Dzator, and Savage (2021) has done this research on 45 Sub-Saharan African countries from 1960 to 2017 Research has shown that renewable energy can produce less CO_2 and distort growth. Growth helps to reduce emissions, but that is not good for renewable energy. Institutions need to make a dent in energy and environmental stuff. This is interesting, as the British ex-colonies had better results. Policymakers need to improve the use of renewable energy and strengthen institutions. You need to grow economically while caring for the earth to make the world beautiful and balanced.

According to a study by Kebede, Kagochi, and Jolly (2010), the Sub-Saharan Africa (SSA) region heavily depends on traditional biomass sources, precisely wood fuel, which accounts for 70% of the total energy consumption, which causes environmental and public health issues. As with GDP and population growth, energy consumption also contributes positively. Still, it has been limited by industrial development and low access to electricity of 23%. However, there are regional differences, with eastern African parts reportedly consuming higher energy rates than central African regions. It is also essential to transform agricultural and industrial processes to use energy effectively. Therefore, to support economic development and sustainability, Sub-Saharan Africa should enhance energy diversification, develop renewable technologies, and adopt energy efficiency. Such an integrated approach is necessary to address energy poverty and improve productivity and environmental degradation.

Using a dynamic simultaneous-equation system, Desiree (2019) presents the causal relationship between energy use, CO_2 emissions and GDP in Sub-Saharan Africa (2000 – 2019). It establishes bidirectional causality between GDP and energy consumption, emphasizing energy as an economic growth driver. Likewise, GDP growth and CO2 emissions also have a two-way relationship with economic growth, inducing increased emissions and vice versa. It is observed that high levels of pollution have adverse impacts on electricity consumption. The research points out the necessity of implementing policies that increase energy efficiency, increase renewable investments, and ensure environmental sustainability. Using renewables such as solar and wind and appropriate regulatory reforms could enhance economic growth and reduce environmental damage. It draws attention to the need to achieve growth against environmental degradation.

A study investigated by Esso and Keho (2016) examines the linkages between energy consumption, economic growth, and CO2 emissions in 12 Sub-Saharan African countries (1971-2010). The research concludes that CO2 emissions are actively increased by the two main factors, energy consumption and economic growth, in the long run. The short-term findings show that economic growth causes CO2 emissions in countries such as Benin, Ghana, and Nigeria. At the same time, reverse causality from CO2 emissions to economic development takes place in Gabon and Togo. Mutual causation occurs in some cases, Nigeria being one of them. Environmentally friendly ways include using cleaner energy sources, improving energy usage, and investing in electricity infrastructure for development without damaging the environment. Personalized environmental strategies are the primary factors for sustainable development.

The ARDL bounds testing and Granger causality approach (1980–2003) are used to study energy-economy linkages in 11 Sub-Saharan African countries by Akinlo (2008). Seventeen studies reported a long-run relationship between energy consumption and economic growth, with positive effects of the former on the latter observed in seven countries (Ghana, Senegal, and Sudan, among them). Gambia, Ghana and Senegal depict a bidirectional nexus between energy consumption and growth. In Sudan and Zimbabwe, energy consumption is driven by economic growth. For instance, no causality was found for Cameroon and Cote d'Ivoire. The results highlight the necessity of energy conservation policies for individuals in countries that effectively counteract economic growth regarding energy efficiency.

Wolde-Rufael (2008) tries to study the direction of causality between energy consumption and economic growth within a multivariate framework for 17 African countries, adding labor and capital as additional variables. He used causality approach and variance decomposition analysis in this paper. However, energy consumption is not altogether insignificant since it grinds causality to economic growth for most of the countries studied. The empirical results are at variance with the neutrality hypothesis and emphasize the need for the consideration of multifactorial in the analysis of the energy-growth nexus. Eggoh, Bangake, and Rault (2011) have indicated methodological improvements and also warned against generalizing the insignificant role of energy, as the robustness of results may vary. They studied the nexus between energy consumption and economic growth in 21 African countries over the period from 1970 through 2006. The author used advanced panel cointegration and causality tests, incorporating cross-country heterogeneities and structural breaks in this paper. The results imply a long-run relationship among energy use, GDP, labor, capital, and prices, and that energy use. The author found an interdependence between energy use and economic growth. And capital and labour are the essential drivers of this relationship.

E. Ikhide (2021) examines the kinship between alternative energy consumption and economic ontogeny in Nigeria, focusing on renewable and nonrenewable sources. Using the ARDL bounds testing glide path, the subject reveals that nonrenewable muscularity, particularly fossil fuels, significantly pushes back economic maturation in the forgetful and long terminal figure, with a 1 % increase going to a 0.056 % ascent in GDP. Conversely, renewable get-up-and-go consumption negatively impacts economic growth and tightens GDP by 0. 093 % per 1 % increase due to underdeveloped infrastructure and trust in fossil fuels. The combined simulation testified that combined energy expenditure positively influences outgrowth, with a 1 % increase boosting GDP by 1.34 %. These determinations indicate that while renewable vigour is environmentally advantageous, its economic benefits in Nigeria are limited without significant infrastructural development and policy reform. The paper Counselling-A-Law for a Balanced Energy Strategy Incorporating Renewable Energy without Compromising Economic Growth punctuates the need for thrifty planning in transitioning to a sustainable energy system.

A study by OVIKUOMAGBE and OLUWALAIYE (2023) analyses the relationship between DOE uptake, CO2 discharge, and population wellness in 13 sub-Saharan African (SSA) countries from 1982 to 2014, utilizing a panel Vector Autoregression (VAR) framework. Two health indexes — under-five mortality rate (U5MR) and aliveness expectancy at parentage — are employed. Results show that aggregate muscularity wasting disease takes no significant causal encroachment on U5MR or life sentence expectancy, which reflects the "neutrality hypothesis." Yet, the down energy character shows that electricity consumption is indirectly shaped by the under-five death rate, indicating a fracture toward uncontaminating energy as health outcomes worsen. Fossil fuel consumption increases CO2 emanation, significantly impacting animation anticipation and wellness and increasing the need for energy insurance reforms. Shocks from fossil fuels negatively influence health indicators, while mutations in U5MR are mostly due to energy purposes and CO2 emissions. The findings emphasize the detrimental wellness effects of fossil fuels and underscore the role of CO2 emissions in exasperating public health outcomes. The paper advocates for a gradual modulation to cleaner vitality sources like electrical energy, which has been raised by targeted policies and incentives to improve population health while mitigating environmental impairment. The analysis emphasizes the lace nature of health, vigour usance, and environmental degradation in SSA's sustainable development context.

The study by MODUPE and SANI (2022) investigates the causal relationship between energy use and economic increment in Nigeria from 1981 to 2018. In a Granger causality framework, energy consumption was disaggregated into four categories: electricity great power uptake, fuel pump terms, energy capital formation, and coal energy consumption. Preliminary unit root and Johansen Colorado - desegregation tests affirm the stationarity of variables at the first difference and a long-run human relationship among them. The results revealed no bidirectional causality between get-up-and-go use and economic growth, indicating that energy consumption does not directly get economic maturation and vice versa. Even So, there is evidence of unidirectional causality from electrical energy tycoon uptake to economic emergence, patronizing the electricity-growing hypothesis. This implies that electricity use of goods and services significantly influences GDP ontogeny, while former get-up-and-go forms exhibit weaker or no causal effects. The findings underscore the need for Nigeria to diversify its Energy Department sources and heighten its approach to electrical energy to nourish economic development. The survey highlights policy passports focusing on improving energy infrastructure, encouraging investment in diverse free energy sectors, and ensuring a reliable electrical energy supply to pad economic productivity. The inquiry contributes to translating the nuanced get-up-and-go-growth moral force, advocating a targeted scheme to optimize energy utilization in fostering sustainable growth.

Ebhotemhen (2021) examines electricity generation and its effect on economic growth in Nigeria between 1970 and 2018 utilizing Auto regressive distributed lag modeling technique to study both short-term and long-term relationships. It highlights the determinants of electricity generation, such as economic activity level, electricity price, natural gas used, rainfall, installed capacity and net electricity consumption. In the short and long runs, however, economic growth, the price of electricity and the installed capacity have been found to positively and significantly affect electricity generation in Nigeria. This emphasizes improving existing corners and pricing policies to accommodate more electricity generation. Electricity consumption had a positive but statistically insignificant correlation with generation, probably due to the inefficiency of the distribution and transmission.

On the other hand, although gas consumption per capita has a linear effect on generation, it negatively correlates with annual rainfall due to pipeline vandalism and lack of hydropower capacity in the low rainfall areas. The study concludes that the ARDL model is perfect in forecasting. The testing procedures of the model are well organized and have good results. Priorities are given to the expected locations of the hydroelectric plants, citing areas with sufficient rainfall and affordable and appropriate electricity tariffs to raise income and energy-earning opportunities, followed by infrastructure management to prevent energy losses. Several policies should also be implemented to deal with pipeline vandalism and improve the efficiency of gas supply for better electricity generation.

Using data from 1981 to 2018, this study by Okungbowa and O. Abhulimen (2021) seeks to assess the impact of disaggregated energy consumption on the productivity of the Nigerian industry using the Error Correction Model (ECM). Energy variables analyzed in this study include petroleum, electricity consumption, natural gas, coal, energy prices, and physical and human capital. The study attempts to determine these relations in the shorter and long run with respect to these factors with the industrial output. The findings also show that coal consumption, energy price, and physical capital were positively and significantly associated with industrial productivity. Natural gas and electricity consumption negatively impact industrial output because of various inefficiencies related to low supply, expensive costs, and the use of alternative sources. It is also possible that human capital, with all its positive attributes in theory, constrains productivity, perhaps because of the ill employment of skills. Results from the Error Correction Model (ECM) support a long-run relationship; however, deviations are corrected at the rate of 63 % per year. As for the model estimates, diagnostic tests conducted on them revealed that the data did not possess any form of heteroscedasticity or serial correlation. Based on the above-mentioned facts, the authors of the study suggest that energy consumption has an impact on industrial productivity in Nigeria but not uniformly. For instance, coal consumption and energy prices have encouraging impacts; natural gas and electricity consumption, on the other hand, have adverse consequences. Overall, the paper proposes sectoral policies targeting electricity consumption in industry, electricity subsidies for the industry sector, and measures to maintain quality energy to enhance productivity.

3. METHODOLOGY

3.1 Theoretical Framework:

In case of time series data, variables need to be checked for stationarity before conducting estimation. In stationarity, the mean and variance of the time series variable do not change, i.e., the variable has a constant mean with time. It is essential to check for stationarity through a unit root test for time series data. The Augmented Dickey and Fuller unit root test is widely used to check for stationarity in the time series data.

After conducting the stationarity test, cointegration test is needed to discover both short term and long-term integration of variables. The study used the autoregressive distributed lag (ARDL) method proposed by Pesaran and Shin (1995) for this purpose. The ARDL model is widely used to analyze economic scenario by explaining the change in economic variable over time. This model is usually consistent with small sample data and can be applicable for variables in different orders. In this model, both the dependent and independent variables are related in present and historical times (lagged values). In this study, ARDL model was used to estimate the relation between economic growth, temperature, energy consumption and other variables. However, before using the model, we made sure that the error terms have no autocorrelation with each other and the variables have no presence of heteroscedasticity. In order words, the variables we used had the constant mean and variance over time. The data we used also followed normal distribution.

3.2 Model Speficifation

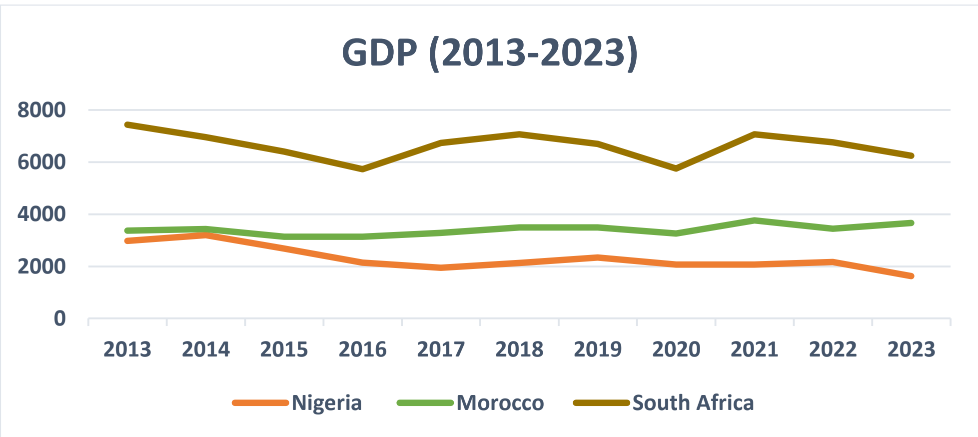
For the purpose of this research, we collected data from secondary sources from Nigeria, Morocco and South Africa. These countries are considered to be one of the wealthiest nations of Africa. We used variables such as GDP per capita (in USD), overall and renewable energy consumption (ktoe per capita), and CO2 emission rate (tons).
Dědeček and Dudzich (2022) explains how GDP per capita can be used as a parameter to determine the well-being of a country. Despite methodical restrictions, it is believed to provide a perfect snapshot of the economics development of a country. Hence, in this study we use GDP per capita (in USD) as the variable to show the trend of economic growth.

Wang, Li, Fang, and Zhou (2015) argues in the research how energy consumption (ktoe per capita) and CO2 emission (tons) are strongly associated with the economic growth. There have been a large number of researches over the years that have soon the relationship among energy consumption, CO2 emission and economic growth. Therefore, this study used these variables to understand how theses energy and climate variables affects economic growth.

Wang, Dong, Li, and Wang (2021) shows that despite the consumption of renewable energy being associated with political, financial, economic, and composite risks, there is a positive effect of renewable energy consumption to economic growth. Hence, this study used renewable energy consumption (ktoe per capita) as a variable.

To conduct this study, these data were collected within the span of 1999 to 2023 from the World Bank's *World Development Indicators*. They were kept in their level form.

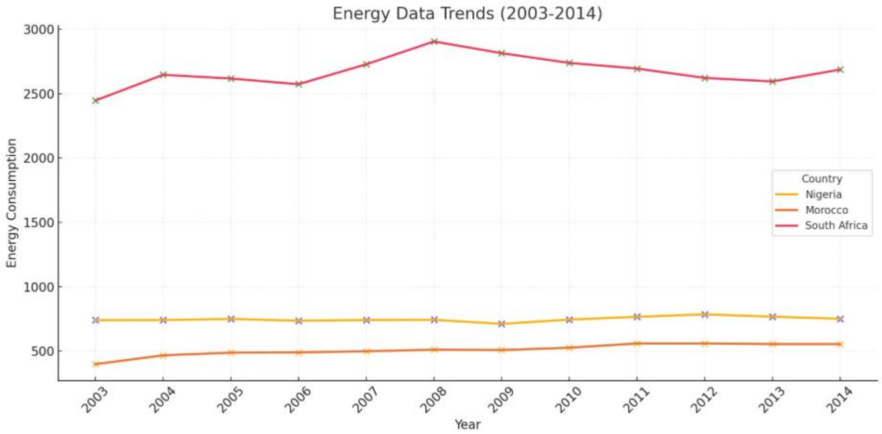
Fig 1: GDP per Capita (USD) for Nigeria, Morocco and South Africa (2013-2023)



Source: World Development Indicators

The above figure (Fig 1) shows the GDP per capita (in USD) for the last ten years of the countries we selected for this study. Only Nigeria has seen a downward trend in its GDP per capita among the three.

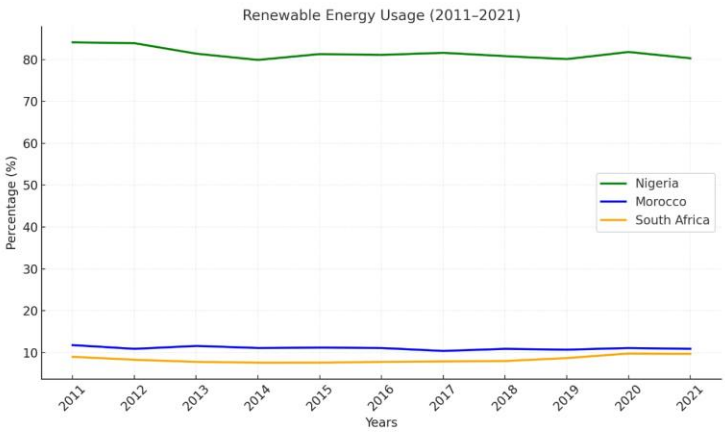
Fig 2: Energy consumption (ktoe) for Nigeria, Morocco and South Africa (2013-2023)



Source: World Development Indicators

The above figure (Fig 2) shows the Energy consumption (ktoe) for the last ten years of the countries we selected for this study. We assume that the country with a bigger economy uses more energy. Considering the higher GDP per capita for South Africa (Fig 1), the energy consumption for South Africa is also higher.

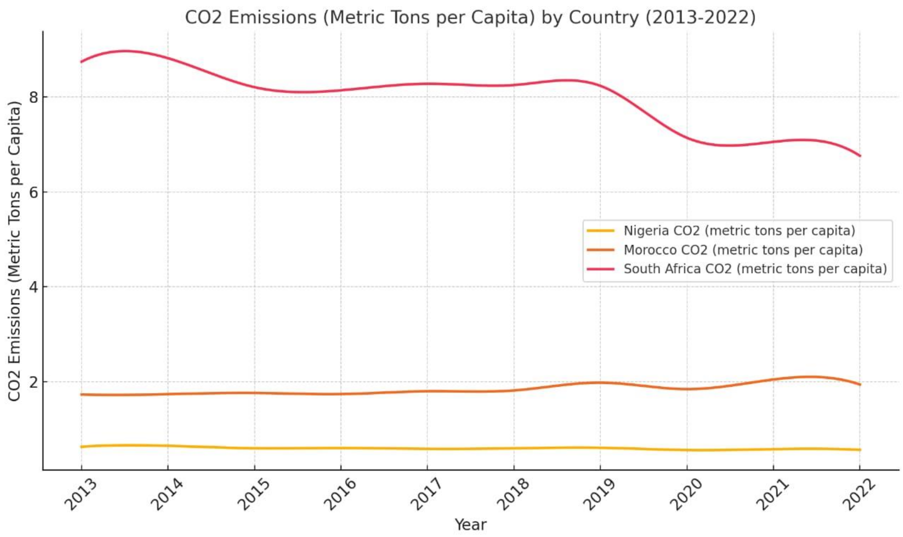
Fig 3: Renewable energy consumption (ktoe) for Nigeria, Morocco and South Africa (2013-2023)



Source: World Development Indicators

The above figure (Fig 3) shows that Nigeria has higher usage of renewable energy sources compared to the other two countries.

Fig 4: CO2 emissions for Nigeria, Morocco and South Africa (2013-2023)



Source: World Development Indicators

As South Africa's energy consumption has been higher than others in the last ten years, the CO2 emission rate is also higher than that of the other two countries (Fig 4).

As the data and variables fulfil the criteria to conduct the ARDL model, this study found the perfect way to explain how the climate and energy variable along with some economic variables brought the changes in the overall economic growth for the selected countries.

The ARDL model used for this study would be,

$$\Delta GDP = \alpha 0 + \beta 1 \sum_{i=1}^{p} GDPt + \gamma 1 \Delta GDPt - 1 + \beta 2 \sum_{i=1}^{q} Energyt + \gamma 2\, \Delta\, Energyt - 1$$
$$+ \beta 3 \sum_{i=1}^{q} Renewable\ energyt + \gamma 3\, \Delta\, Renewable\ energyt - 1$$
$$+ \beta 4 \sum_{i=1}^{q} CO2t + \gamma 4\, \Delta\, CO2t - 1 + \varepsilon$$

where $p \geq 1$ and $q \geq 0$; in this study the lag order is same for all variables.

While coefficient β indicates short term dynamics, γ indicates long term dynamics.

The null hypothesis, $H_0 = \gamma_n = 0$

The alternative hypothesis, $H_1 = \gamma_n \neq 0$

If the bound test F statistics is lower than the lower bound value, we accept the null hypothesis, i.e., no co-integration. However, if the bound test F statistics is greater than the upper bound value, we reject the null hypothesis, i.e., the variables have long run equilibrium. If the value of F statistics is between the upper and lower bound value, the hypothesis test in inconclusive.

After conducting the test, the model needs to be tested for stability. LM serial correlation test and the cumulative sum of recursive residuals (CUSUM) tests were conducted for the purpose.

If the curve is between the critical regions at a 5% significance level, it authenticates the stability of the model.

4. RESULT AND DISCUSSION OF FINDINGS

To conduct this analysis, this study opted for Augmented Dickey and Fuller unit root test to test for stationarity. For this purpose, we assume the null hypothesis to be non-stationary, i.e., the time series has unit root. After calculating the test statistics, we checked if the calculated value is less 5% critical value. This study chose the 5% significance level, since it creates a perfect balance between Type I and Type II errors.

The table below (Table 1) shows the result of the Augmented Dickey and Fuller unit root test for the selected countries.

Table.1. Unit root test for stationarity

Variable	Calculated value
Nigeria	
GDP	-1.677
Energy consumption	-0.615
Renewable energy consumption	0.068
CO2	0.353
Morocco	
GDP	-0.651
Energy consumption	-0.920
Renewable energy consumption	-0.202
CO2	-1.626
South Africa	
GDP	0.5727
Energy consumption	-0.679
Renewable energy consumption	0.074
CO2	1.478

As these calculated values of the selected variables are higher than the critical value of the 5% significance level (-2.978), we fail to reject the null hypothesis. Hence, the time series variables used in this study are non-stationary.

Therefore, these study uses the First Difference model for time series data that can transform the non-stationarity of the data into stationarity. Then the study uses the Autoregressive Distributed Lag (ARDL) method to understand the co-integration and the effect of the energy and climate variable on economic growth, i.e., GDP per capita for Nigeria, Morocco, and South Africa. However, before using the ARDL model, the study made sure, the dataset follows all the assumptions.

- ***Nigeria:***

The table.2. shows the result of ARDL bound test for co-integration for Nigeria

Table.2. ARDL bound test for Nigeria

F (4, 25)	1.94
Prob > F	0.1353
R-squared	0.2367
Adjusted R-squared	0.1145

While estimating the result for Nigeria, this study found that the p-value 0.1353 is greater than the significance level (0.05). As we fail to reject the null hypothesis, the model is not statistically significant. Although the higher R-squared (0.2367), the lower value of adjusted R-squared (0.1145) indicates that the capacity to explain the changes in GDP of Nigeria through the other independent variables is very limited.

Table.2.1. Short-run coefficient for Nigeria

The dependent variable is GDP per capita			
Variable	Co-efficient	S.E.	t-statistics
d_nigeriaenergy	.7634879	.4945127	1.54
d_nigeriarenewable	-.6681558	4.631601	-0.14
d_nigeriac02	1227.835	593.3125	2.07
_cons	74.31224	71.42303	1.04

Table.2.2. Long-run coefficient for Nigeria

The dependent variable is GDP per capita			
Variable	Co-efficient	S.E.	t-statistics
nigeriaenergy	1.279922	.2796829	4.58
nigeriarenewable	-146.32918	118.127082	-3.3
nigeriac02	-3608.8724	3966.693	-3.3
_cons	13355.19	3168.471	4.22

The above tables present the short and long run dynamics for Nigeria. While in the short run, the energy consumption and CO2 emission have positive impact on the GDP of Nigeria, in the long run CO2 emission has a negative impact on the GDP per capita for Nigeria. Renewable energy consumption has negative impact on the GDP per capita of Nigeria.

The study has conducted LM serial correlation test and the cumulative sum of recursive residuals (CUSUM) test for checking the stability of the model.

Table.2.3. Breusch-Godfrey LM test for Nigeria

Breusch-Godfrey LM test for autocorrelation	
chi2	4.012
Prob > chi2	0.2601

Since the p-value (0.2601) is greater than the 5% significance level of 0.05, we fail to reject the null hypothesis. This suggests that the model this study used for Nigeria doesn’t have autocorrelation.

Fig 5: CUSUM test for Nigeria

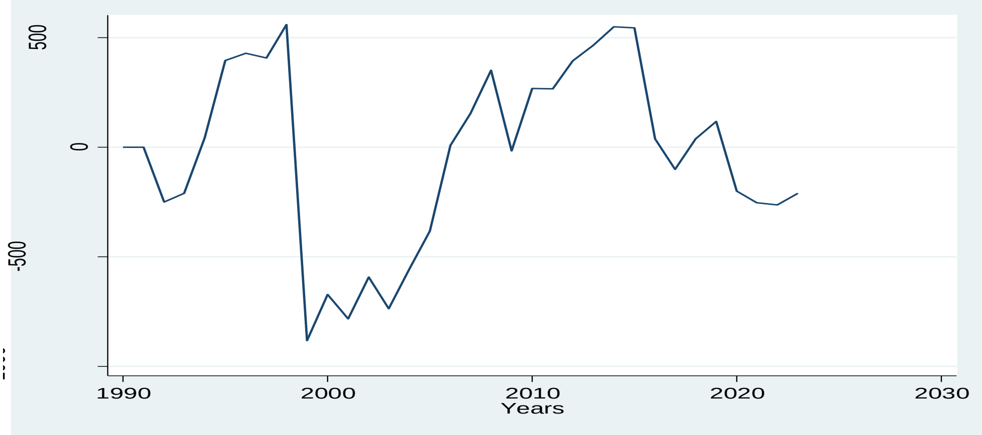
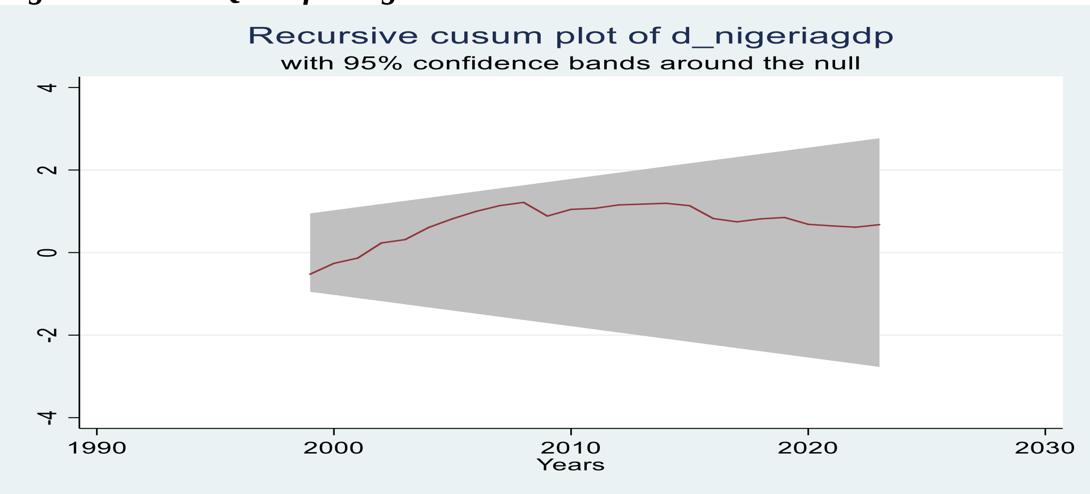


Fig 6: CUSUMSQ test for Nigeria



The figure (Fig 5) indicates that the relationship among the variables might have changed over time. The figure (Fig 6) suggests that the outcome of the model is reliable since the CUSUMSQ line stays within the control region.

- ***Morocco:***

The table.3. shows the result of ARDL bound test for co-integration for Morocco

Table.3. ARDL bound test for Morocco

F (5, 25)	3.34
Prob > F	0.0191
R-squared	0.4002
Adjusted R-squared	0.2803

As the p-value (0.0191) is less than than the significance level (0.05), we reject the null hypothesis. The model is statistically significant. Although the higher R-squared (0.4002), the lower value of adjusted R-squared (0.2803) indicates that the capacity to explain the changes in GDP of Morocco through the other independent variables is very limited.

Table.3.1. Short-run coefficient for Morocco

The dependent variable is GDP per capita			
Variable	Co-efficient	S.E.	t-statistics
d_moroccoenergy	.7581495	.3110152	2.44
d_moroccorenewable	6.461338	14.85822	0.43
d_moroccoco2	50.20255	95.04757	0.53
_cons	140.321	36.1162	3.89

Table.3.2. Long-run coefficient for Morocco

The dependent variable is GDP per capita			
Variable	Co-efficient	S.E.	t-statistics
moroccoenergy	.4610183	.1816289	2.54
moroccorenewable	10.08912	12.78091	0.79
moroccoco2	1470.8183	1042.9917	3.25
_cons	1470.8183	1042.9917	3.25

The above tables present the short and long run dynamics for Morocco. Both in the short and long run, the energy consumption, renewable energy consumption and CO2 emission have positive impact on the GDP per capita for Morocco.
The table below (Table.3.3.) shows the result of LM serial correlation test.

Table.3.3. Breusch-Godfrey LM test for Morocco

Breusch-Godfrey LM test for autocorrelation	
chi2	0.192
Prob > chi2	0.9082

Since the p-value (0.9082) is greater than the 5% significance level of 0.05, we fail to reject the null hypothesis. This suggests that the model this study used for Morocco doesn't have autocorrelation.

Fig 7: CUSUM test for Morocco

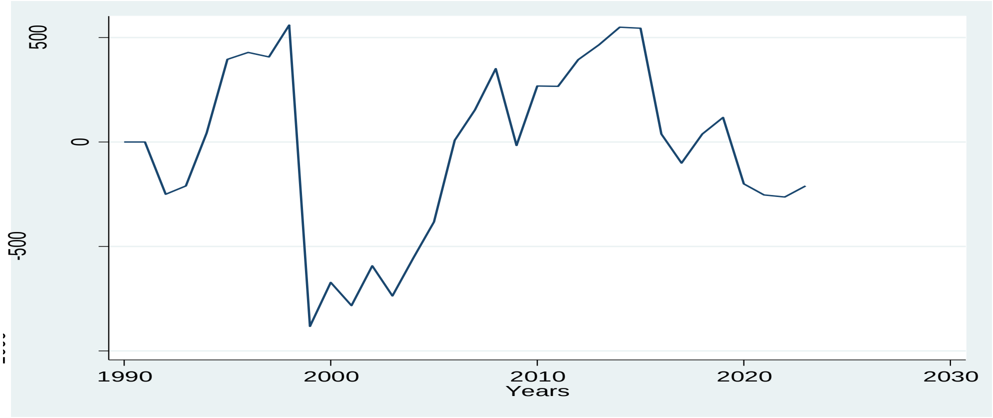
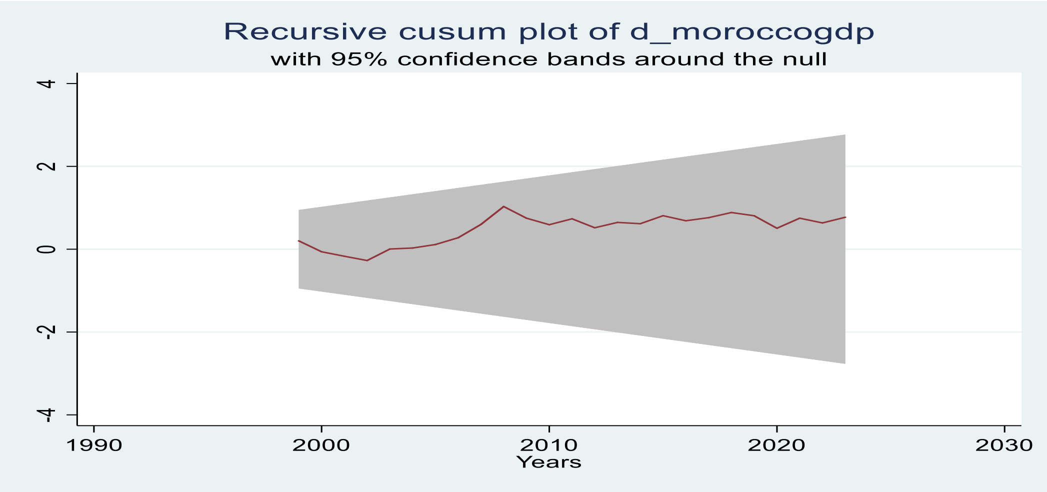


Fig 8: CUSUMSQ test for Morocco



The figure (Fig 7) indicates that the relationship among the variables might have changed over time. The figure (Fig 8) suggests that the outcome of the model is reliable since the CUSUMSQ line stays within the control region.

- ***South Africa:***

The table.2.2 shows the result of ARDL bound test for co-integration for South Africa.

Table.4. ARDL bound test for South Africa

F (18, 10)	3.67
Prob > F	0.0203
R-squared	0.8684
Adjusted R-squared	0.6315

As the p-value (0.0203) is less than than the significance level (0.05), we reject the null hypothesis. The model is statistically significant. Although the higher R-squared (0.8684), the lower value of adjusted R-squared (0.6315) indicates that the capacity to explain the changes in GDP through the other independent variables is very limited.

Table.4.1. Short-run coefficient for South Africa

The dependent variable is GDP per capita			
Variable	Co-efficient	S.E.	t-statistics
d_southafricaenergy	0.7179411	.2376668	4.53
d_southafricarenewable	569.0401	1554.7296	1.25
d_southafricaco2	-1538.99803	2326.6207	-3.91
_cons	309.9168	245.8362	1.26

Table.4.2. Long-run coefficient for South Africa

The dependent variable is GDP per capita			
Variable	Co-efficient	S.E.	t-statistics
southafricaenergy	.5271451	.2009601	2.62
Southafricarenewable	-408.23703	301.4495	-2.21
southafricaco2	-534.0597	763.139	-1.41
_cons	11553.77	4524.684	2.55

The above tables present the short and long run dynamics for South Africa. In the short run, the both the energy and renewable energy consumption have positive impact while CO2 emission has negative impact on the GDP per capita for South Africa. However, in the long run, only energy consumption has the positive impact where both renewable energy consumption and CO2 emission impact negatively on the economic growth indicator, i.e., the GDP per capita for South Africa.

The table below (Table.4.3.) shows the result of LM serial correlation test.

Table.4.3. Breusch-Godfrey LM test for South Africa

Breusch-Godfrey LM test for autocorrelation	
chi2	3.211
Prob > chi2	0.5232

Since the p-value (0.5232) is greater than the 5% significance level of 0.05, we fail to reject the null hypothesis. This suggests that the model this study used for South Africa doesn't have autocorrelation.

Fig 9: CUSUM test for South Africa

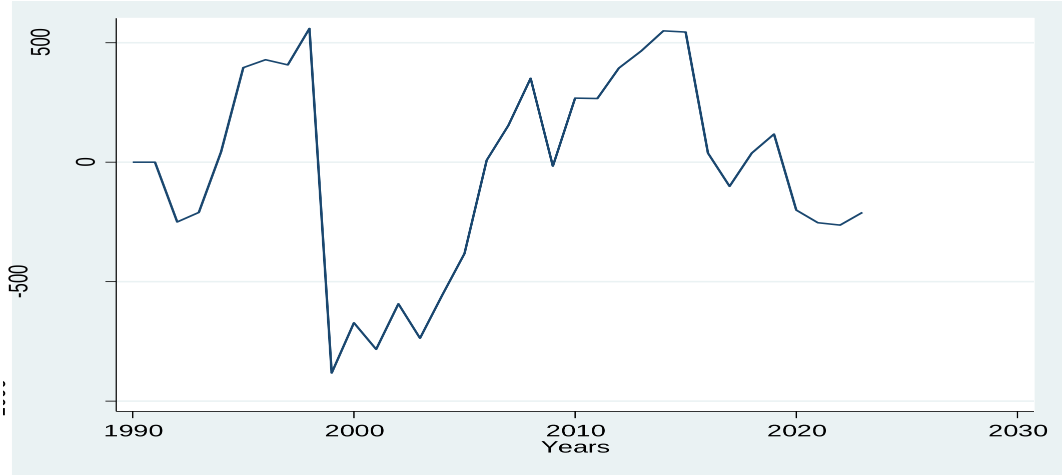
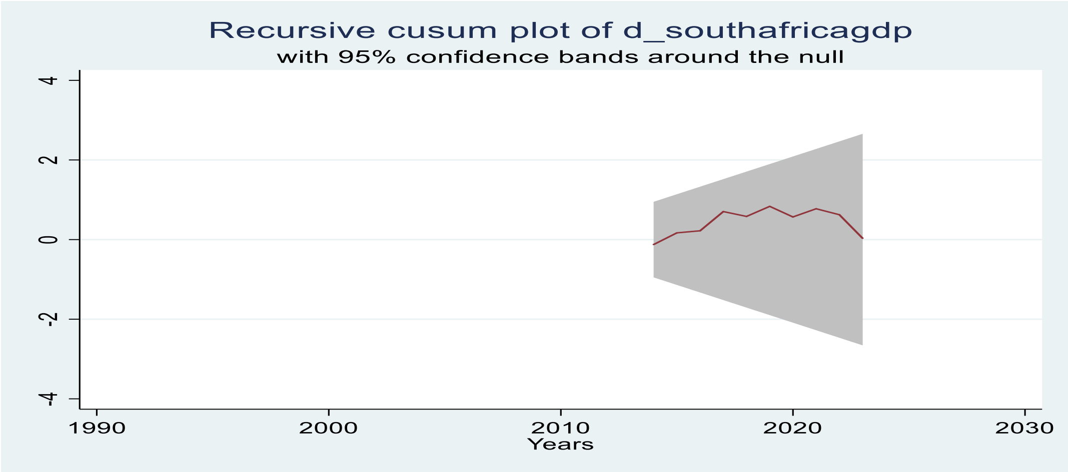


Fig 10: CUSUMSQ test for South Africa



The figure (Fig 9) indicates that the relationship among the variables might have changed over time. The figure (Fig 10) suggests that the outcome of the model is reliable since the CUSUMSQ line stays within the control region.

5. CONCLUSION AND POLICY RECOMMENDATION

Industrialization and production are two of the much-needed elements for improving the economy. Society wishes to fulfil the demands of the people living in it. Hence, despite the limited resources, the economy must ensure the supply of elements to satisfy people's needs. While massive production keeps the economy going, it also affects the environment of the people living in it. As the world is moving towards a better environment for future generations, the use of renewable energy resources is also increasing. This study shows that renewable energy might slow the economy's growth. However, in the long run, renewable energy resources have a negative impact on CO2 emissions but a positive impact on economic growth indicators, such as GDP per capita. African countries can use renewable energy sources to reduce environmental damage and increase economic growth. Along with investing more, the countries should spend more on the research and development sector to make renewable energy sources like wind, solar, water more accessible, less expensive options. They can also support small industries that are working to invent, promote renewable energy sources. The governments can come up with subsidies, tax reduction and other policies for the people who are using or doing business with renewable energy sources. The countries can also collaborate with international organizations and neighboring countries to allow trade of renewable energy and allow the citizens a better access to technologies. In the end, we urge the governments to come together and find alternative ways to reduce the usage of fossil fuels. They can popularize renewable energy resources by creating awareness and investing more in renewable energy. To make the world a better place for the future, it is high time governments take immediate action for themselves and others.

REFERENCES

Acheampong, A. O., Dzator, J., & Savage, D. A. (2021). Renewable energy, CO2 emissions and economic growth in sub-Saharan Africa: Does institutional quality matter? *Journal of Policy Modeling*, *43*(5), 1070–1093. https://doi.org/10.1016/j.jpolmod.2021.03.011

Akinlo, A. (2008). Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. *Energy Economics*, *30*(5), 2391–2400. https://doi.org/10.1016/j.eneco.2008.01.008

Aleshinnloye, M. F., & Bariki, S. S. (2022). Investigating the Causal Relationship Between Energy Consumption And Economic Growth In Nigeria, *Journal Of Economics And*

Allied Research 7 (3), 166–168. Https://Jearecons.Com/Index.Php/Jearecons/Article/View/24

Ali, M. U., Gong, Z., Ali, M. U., Wu, X., & Yao, C. (2020). Fossil energy consumption, economic development, inward FDI impact on CO2 emissions in Pakistan: Testing EKC hypothesis through ARDL model. *International Journal of Finance & Economics*, *26*(3), 3210–3221. https://doi.org/10.1002/ijfe.1958

Aliyu, A. K., Modu, B., & Tan, C. W. (2017). A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria. Renewable and Sustainable Energy Reviews, 81, 2502–2518. https://doi.org/10.1016/j.rser.2017.06.055

Dědeček, R., & Dudzich, V. (2022). Exploring the limitations of GDP per capita as an indicator of economic development: a cross-country perspective. *Review of Economic Perspectives*, *22*(3), 193–217. https://doi.org/10.2478/revecp-2022-0009

Desiree, B. (2019, March 31). Dynamic Analysis of Energy Consumption and Environmental Impact on GDP in Sub-Saharan Africa. Retrieved from https://resdojournals.com/index.php/JEEPO/article/view/87

Eggoh, J. C., Bangake, C., & Rault, C. (2011). Energy consumption and economic growth revisited in African countries. *Energy Policy*, *39*(11), 7408–7421. https://doi.org/10.1016/j.enpol.2011.09.007

Esso, L. J., & Keho, Y. (2016). Energy consumption, economic growth and carbon emissions: Cointegration and causality evidence from selected African countries. *Energy*, *114*, 492–497. https://doi.org/10.1016/j.energy.2016.08.010

Ikhide, E. E., Department of Economic Development and Social Studies, & National Institute for Legislative and Democratic Studies (NILDS). (2021). Alternative Energy Consumption and Economic Growth In Nigeria, *Journal of Economics and Allied Research 6, Issue 1*

Kebede, E., Kagochi, J., & Jolly, C. M. (2010). Energy consumption and economic development in Sub-Sahara Africa. *Energy Economics*, *32*(3), 532–537. https://doi.org/10.1016/j.eneco.2010.02.003

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financial Innovation*, *6*(1). https://doi.org/10.1186/s40854-019-0162-0

Kivyiro, P., & Arminen, H. (2014). Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. *Energy*, *74*, 595–606. https://doi.org/10.1016/j.energy.2014.07.025

Okungbowa, F. O., & Abhulimen, M. O. (2021). Energy and Industrial Productivity in Nigeria: A Disaggregated Case. In Benson Idahosa University, Journal of Economics and Allied Research, 6(1), 201–203)

Osobajo, O. A., Otitoju, A., Otitoju, M. A., & Oke, A. (2020). The Impact of Energy Consumption and Economic Growth on Carbon Dioxide Emissions. *Sustainability*, *12*(19), 7965. https://doi.org/10.3390/su12197965

Oyedele, O., & Oluwalaiye, O. B. (2023). Energy Consumption, Co2 Emission and Population Health in Sub-Saharan Africa, *Journal of Economics and Allied Research, Vol. 8, Issue 3,*

Pesaran, M. H., & Shin, Y. (1995). *An autoregressive distributed lag modelling approach to cointegration analysis* (Vol. 9514, pp. 371-413). Cambridge, UK: Department of Applied Economics, University of Cambridge.

Singh, S. (2024, November 14). Natural Resources in Africa: Abundant wealth from Arable land, water, oil, natural gas, minerals, forests,. ScienceNeo. Retrieved from https://www.scienceneo.com

Wang, S., Li, Q., Fang, C., & Zhou, C. (2015). The relationship between economic growth, energy consumption, and CO2 emissions: Empirical evidence from China. *The Science of the Total Environment*, *542*, 360–371. https://doi.org/10.1016/j.scitotenv.2015.10.027

Wang, Q., Dong, Z., Li, R., & Wang, L. (2021). Renewable energy and economic growth: New insight from country risks. *Energy*, *238*, 122018. https://doi.org/10.1016/j.energy.2021.122018

Wesseh, P. K., & Lin, B. (2018). Energy consumption, fuel substitution, technical change, and economic growth: Implications for CO2 mitigation in Egypt. Energy Policy, 117, 340–347. https://doi.org/10.1016/j.enpol.2018.03.022

Wilson, E. & Department of Economics, Edo State University. (2021). Economic Growth and Electricity Generation in Nigeria, *Journal of Economics and Allied Research*, 6 (1), 264–266

Wolde-Rufael, Y. (2008). Energy consumption and economic growth: The experience of African countries revisited. *Energy Economics*, *31*(2), 217–224. https://doi.org/10.1016/j.eneco.2008.11.005