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Energy Utilization, Financial Sector Development, Economic Growth, and Carbon Emissions in West Africa

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Abstract
In this paper, we explored the influence of energy utilization, financial sector development, and economic growth on carbon emissions in West Africa. The study utilized panel data covering the periods 1995–2014 and 1995–2022 for some variables due to the availability of data for twelve (12) West African countries. The study was based on the framework of the Environmental Kuznets Curve (EKC) hypothesis. The data analysis follows the cointegrating regression analysis under the fully modified ordinary least squares (FMOLS) approach. The findings of the study indicate that the EKC hypothesis is valid within the West African region. Further, financial development and energy utilization were observed to exert a positive and significant effect on carbon emissions in West Africa. The interactive models also indicated that both the interaction of financial development and economic growth, as well as the interaction of financial development with energy utilization, exerted a positive and significant effect on carbon emissions in West Africa. Given these findings, the study concluded that the financial sector in the West African region seldom gives the eco-friendliness of the investments they are making a thorough consideration, and financial institutions in West African nations are motivated by profit and, as such, only lend money quickly for short-term investments, which may be inappropriate for promoting green investment.

Keywords
Green investments, Environmental Kuznets Curve, Carbon intensity, Emissions

INTRODUCTION

High carbon emissions have been traced to economic growth in the field of environmental economics. This is linked to the fact that in the process of striving for greater output growth, there will be likelihood of increased emissions of carbons into the atmosphere. A significant increase in carbon emissions may result from the increased demand for housing and food due to increased population density, which forces environmental degradation through tree-cutting and a reduction in biodiversity overall to accommodate the expanding population (Asafu-Adjaye, 2003). Developing economies, such as countries within the West African region, are at risk of environmental degradation as a result of using non-clean energy sources because they are cheaper to use to power economic activities. This arises from due to their striving to catch up and converge with developed economies (Mesagan & Olunkwa, 2020; Olaoye & Dauda, 2022). This view led to the development of the Environmental Kuznets Curve hypothesis which stipulates that environmental degradation is high at the early stage of economic growth since industries are likely to eject waste and other discharges into the environment. Such wastes which are in the various states of matter are likely to increase the carbon emissions which endangers environmental quality. However, an achievement of the desired level of growth will prompt the need to control pollution by using more clean energy sources, with greater environmental consciousness which tantamount to improved quality of the environment (Tabash, Mesagan, & Farooq, 2022). Thus, the atmospheric greenhouse gasses (GHGs) which is an outcome of intensive industrial activities reduces at this stage compared to the early stage of growth.

It has been pointed out by Bond *et al*. (2004) that carbon dioxide (CO_2) is the most prevalent greenhouse gas in the atmosphere. More than 60% of greenhouse gases in the atmosphere are caused by the burning of fossil fuels and the production of cement (Olubusoye & Musa, 2020). Despite being a necessary component of life, carbon emissions that are too high have a detrimental effect on the ecosystem (Zehnder & Svensson, 1986; Khanna, Bakshi, & Lee, 2008; Arrigoni, Beckett, Ciancio, & Dotelli, 2017). The atmosphere contains the GHGs by nature. As noted by Kweku *et al*. (2018), GHGs retain heat and keep the planet warm enough to support life. Nevertheless, the earth's climate heats up over its average level when these GHGs build up and surpass the naturally required threshold. Rising sea levels due to climate change have resulted in flooding, less rainfall, and other calamities that have a detrimental effect on food security, and have made poverty rates higher. Africa is more severely affected by climate change, particularly in areas where agriculture is the primary economic activity (Stocker, et al., 2013; Olubusoye & Musa, Carbon emissions and economic growth in Africa: Are they related?, 2020).

The West African region has witnessed a rising trend in carbon emissions in recent times. As at 2010, the level of carbon emissions in the area was 94.6 million metric tonnes which rose substantially to 106.8 million metric tonnes and 126.1 million metric tonnes for 2012 and 2015 respectively. This rising trend continued to 140.1 million metric tonnes and 163.0 million metric tonnes for 2017 and 2019 respectively. However, it declined to 162.7 million metric tonnes in 2020 due to the Covid-19 pandemic which jeopardized industrial production in the region. The year 2021 and 2022 was later marked with a rising carbon emissions to the tune of 179.1 million metric tonnes as at 2020 (Statistica , 2023). The trend of this is presented in Fig. 1 over the period under review.

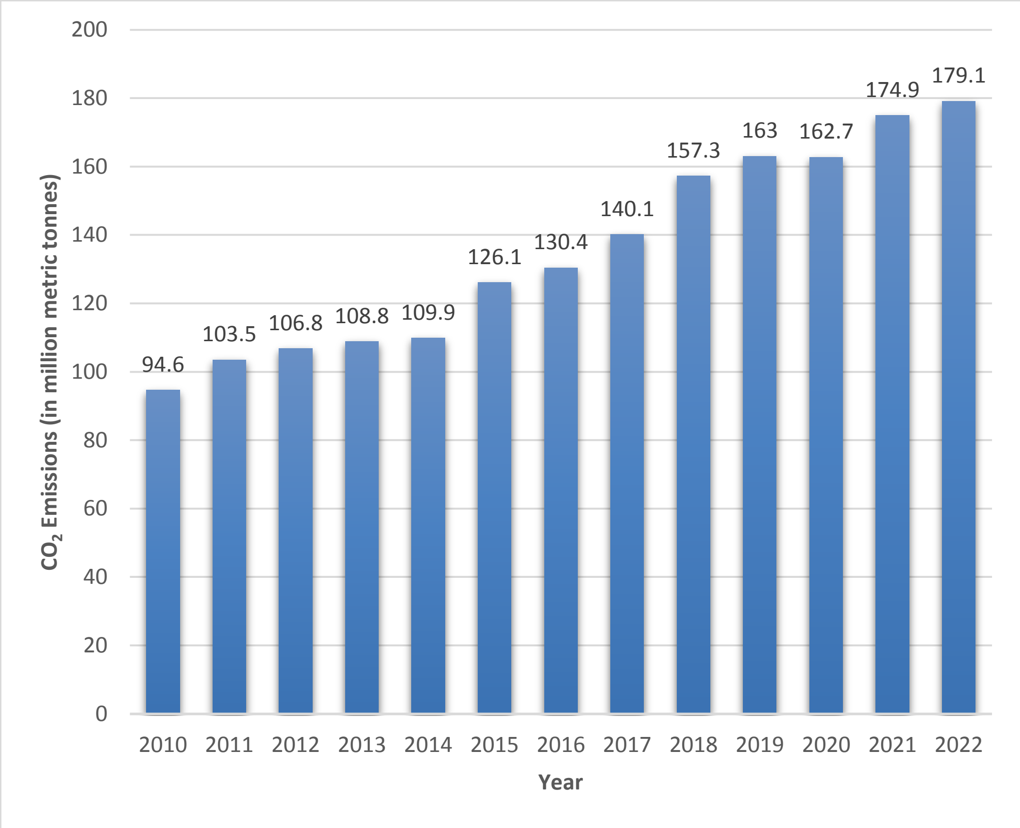

Fig. 1 Trend in West Africa's CO_2 emission in million metric tonnes, 2010-2022

For the individual West African countries, similar trend exists on the pattern of carbon emissions in the countries within the region. This can be observed from Fig. 1 for the twelve West African countries under consideration.

It is observable from Fig. 2 (below) that countries in the West African region exhibit rising pattern of carbon emissions over the years. Though Guinea-Bissau, Nigeria and Sierra Leone exhibited a declining trend in the 1990s, subsequent periods were marked with an upsurge in emissions. It is also worthy of note that the Nigeria and Togo exhibits a highly volatile pattern in the carbon emissions throughout the period under review.

Earlier, we have identified the role of economic growth in stimulating carbon emissions in an economy via the EKC hypothesis. It is also worthy of note that the financial system has a crucial role to play in either intensifying or reducing carbon emissions in an economy. Meanwhile, such role can either be positive or negative, and the transmission mechanism is through energy utilization. In line with Cheng, Chien & Lee (2020), a developed financial system encourages the advancement of technology. It eases credit restrictions, builds infrastructure, and sparks industrialization (Lu et al., 2021). The immediate result is a rise in consumer earnings and employment as well as a decrease in business costs, which encourages businesses to invest more in the generation of renewable energy (Tinta, 2022). This causes an increase in energy usage indirectly. However, if businesses do not invest in cleaner energy, carbon emissions will increase due to increased energy utilization.

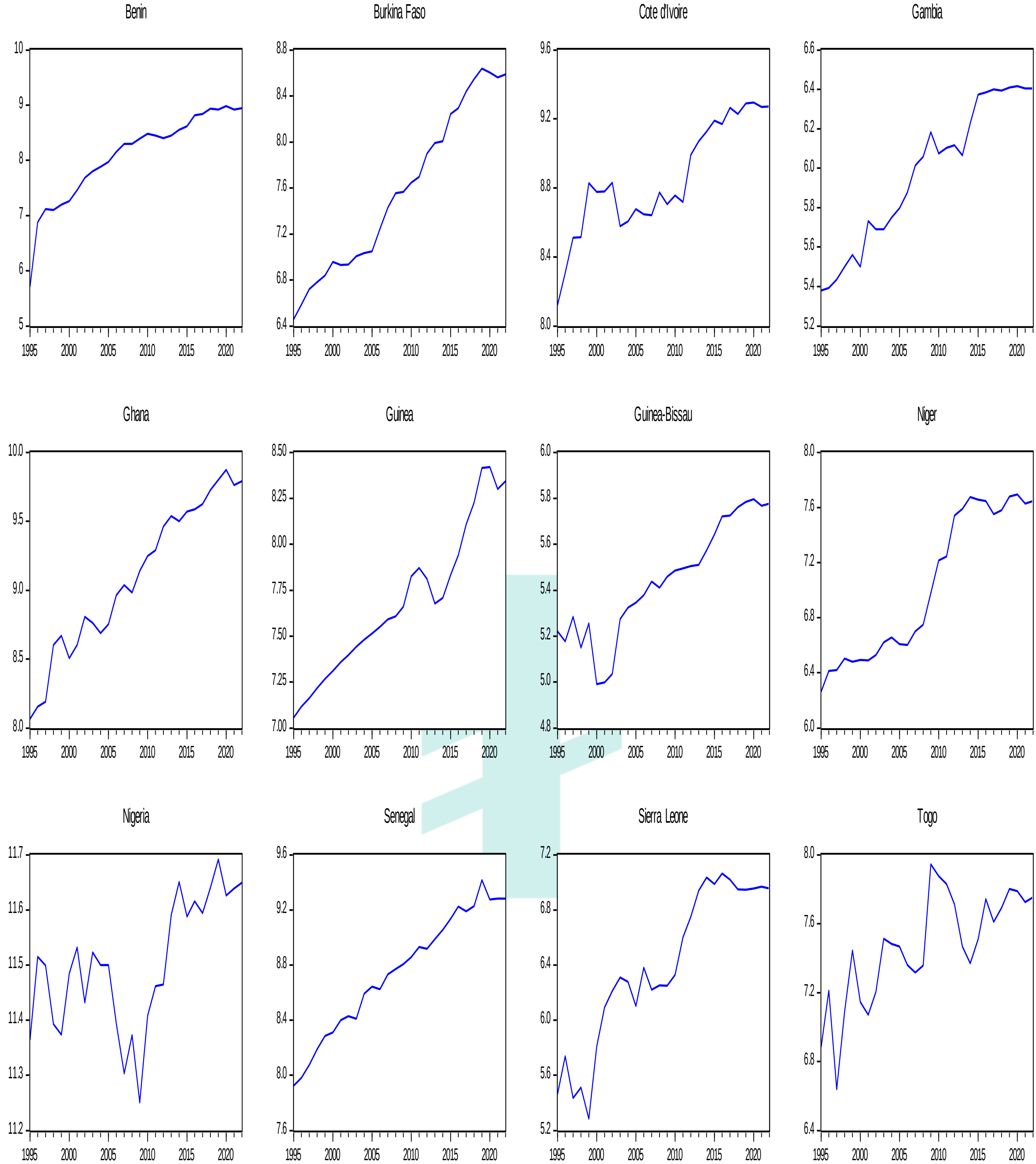

Fig. 2 Trend in CO_2 emissions in West African countries

It is within the above framework that this study seeks to examine the interaction among energy utilization, financial sector development, economic growth, and carbon emissions in West Africa. The specific objectives include to establish the existence or non-existence of the environmental Kuznets curve (EKC) hypothesis in West Africa; to ascertain the effect of financial development on carbon emission in West African economies; to ascertain the effect of financial development in economic growth on carbon emission in West African economies; to investigate the effect of energy utilization on carbon emission in energy-dependent West African countries; and to investigate the effect of financial development in energy utilization on carbon emission in energy-dependent West African countries.

LITERATURE REVIEW

The theoretical basis of this study is derived from the work of Ye et al. (2021). This framework tries to bring forth the connection between financial sector development and environmental quality. Two schools of thought have been put forward to explain how financial development could affect the quality of the environment. At the first instance, it is believed that an efficient financial intermediation could spur opportunities for investment and increase the lending power of financial institutions to the business sector and households. The resultant effect will be increased investments by these sectors in the area of new financial assets, the procurement of consumables of higher value, and expansion of business operations. This increases the amount of energy consumed on production in the business sector, and on household appliances and automobiles. This rising energy consumption pattern increase the release of carbon emissions and other pollutants into the environment (Abbasi & Riaz, 2016; Shahbaz, Shamim, & Aamir, 2010).

Another perspective is that a financial system that is quite developed with a sound and stable capital market offers the leeway for funds to be invested in the renewable energy and loans along with equity financing in the area of green energy projects. A financial system that is well-developed offers an opportunity for the provision of credit to projects that are eco-friendly at lower cost. Additionally, foreign direct investment may spur technical innovation among local businesses, which would lower energy consumption (Jalil & Feridun, 2011). Consequently, higher energy substitution (which lowers energy consumption and CO_2 emissions) may be encouraged by financial development Ye, Khan, Wu, Shah, & Abbas (2021). Financial development strategies, according to Haseeb et al. (2018), should support technological advancement, reduce carbon emissions, and boost domestic manufacturing.

On the link between energy use and economic growth of a nation, the Environmental Kuznets Curve (EKC) hypothesis provides the theoretical basis. According to the EKC hypothesis, the link between various pollutants and per capita income is structured like an inverted-U. In other words, environmental pressure rises to a certain point and then falls as income rises. Put differently, during the early phases of development, environmental pressure rises more quickly than income, and at higher income levels, it slows down in relation to GDP growth. The transition from a clean agricultural economy to a pollution-based industrial economy to a clean service economy, as well as the inclination of higher income groups to prioritize environmental quality, are some possible causes for this EKC pattern. The work of Kuznets (1973), who proposed a similar link between income disparity and economic progress, is whence the inverted-U relationship gets its name.

Intuitively, the EKC connection makes sense. Due to the reason that increasing output productivity is prioritized over maintaining clean air and water, pollution increases quickly during the early stage of industrialization (Dasgupta, Hong, Laplante, & Mamingi, 2006). Unavoidably, fast expansion leads to increased consumption of natural resources and pollution emissions, both of which worsen the environment. People either do not care about the environmental effects of expansion or are too impoverished to pay for abatement. As income levels grow in the later stages of industrialization, individuals begin to pay more attention to the quality of the environment more, regulatory bodies become more effective, and pollution levels start to drop. Hence, the EKC hypothesis postulates a clearly defined link between the degree of economic activity and environmental pressure, which is characterized as the degree of pollutant concentration or emission flow, resource depletion, etc. An EKC illustrates how changes in a nation's or a large human community's fortunes affect a formally defined metric of environmental quality. The EKC, to put it briefly, are statistical relics that highlight certain significant facets of the collective behaviour of humans in two dimensions. When pollution indicators are plotted against per capita income, the EKC predicts an inverted U-shaped curve (Dinda, 2004).

Several empirical works have been executed to empirically establish the link concerning energy use, financial development, economic growth, and carbon emissions. Sarkodie (2018) investigated the factors influencing pollution and environmental deterioration in 17 African nations between 1971 and 2013, using the error correction model (ECM) and Panel cointegration technique. The findings supported the EKC concept. Using a polynomial formulation, Hundie (Hundie, 2018) applied the ARDL model and discovered evidence that, over time, energy consumption, population, trade openness, and economic growth all have a significant influence on Ethiopia's carbon emissions. The EKC hypothesis is supported by the data from the study's squared GDP. The immediate outcome demonstrates that environmental deterioration is exacerbated by urbanization and energy use. The Toda-Yamamoto study provides proof of the loop causal relationship between urbanization, carbon emissions, and energy consumption.

Adzawla, Sawaneh, & Yusuf (2019) tested the EKC hypothesis about the correlation between greenhouse gases (GHGs) and sub-Saharan Africa's (SSA) economic growth from 1970 to 2012 by using the ordinary least squares (OLS) technique. As suggested by the EKC hypothesis, the analysis found no indication of a turning point. A relationship with an inverted N-shaped relationship is shown by the OLS and VAR, respectively. Overall, the analysis finds that there is a long-term, monotonically declining link between economic growth and environmental quality (using NH_4 emissions as a proxy).

Acheampong, Adams & Boateng (2019) investigated the effects of renewable energy and globalization on carbon emissions in 46 SSA nations between 1980 and 2015 using fixed and random effect models. The EKC theory is supported by the evidence. The outcome also demonstrates that although trade openness exacerbates environmental deterioration, FDI and population growth lower carbon emissions. Demissew & Kotosz (2019) tested the EKC hypothesis in 23 East African countries between 1990 and 2013 by using the Pooled Mean Group (PMG) technique. In the short run, the EKC theory is supported, but it is rejected in the long run.

Tsaurai (2019) examined financial development and carbon emissions in West African nations from 2003 to 2014 using the panel OLS estimation approach. Consistent with the study's findings, the region's financial development exacerbates pollution. Using the first- and second-generation panel co-integration and estimate approach, Ehigiamusoe & Leon (2019) carried out a broad range of research on financial development, economic growth, and energy consumption and carbon emission for 122 economies between 1990 and 2014. In line with the findings, increases in energy consumption, financial development, and economic expansion all contributed to a rise in carbon emissions. It divides the panel's countries into three categories: high, moderate, and low income. The findings further indicated that carbon emissions in high-income nations were disconnected from economic growth and financial development, but in middle-class and low-income countries the opposite was true.

A comparable analysis was carried out for Ghana between 1971 and 2014 by Kwakwa (2019). The study examined the relationship between energy and financial development in order to determine how financial development influences carbon emissions. The study found that the link between financial development and energy usage decreased carbon emissions in Ghana, based on the ARDL methodology and FMOLS. Using the co-integration regression approach (FMOLS and DOLS), Mesagan & Olunka (2020) investigated capital investment, energy consumption, and environmental degradation for African nations between 1981 and 2017. The findings showed that capital expenditure and energy use, respectively, had a favourable impact on environmental degradation in Africa. Furthermore, it was shown that capital investment acted as a moderator for energy consumption in the African continent's effort to reduce pollution.

Rafique et al. (2020) used the Augmented Mean Group to present data from the BRICS between 1990 and 2017. According to the study, long-term CO_2 emissions were lowered by financial development, foreign direct investment, and technical innovation. In a similar vein, Shoaib et al. (2020) (2020) studied the economies of the G8 and D8 in comparison between 1999 and 2013. The panel series was analyzed using the pool Mean Group approach in this study. The findings showed that energy consumption and financial development exacerbate carbon emissions in the D8 and G8 economies.

Using a panel cointegration technique, Bah, Abdulwakil, & Azam (2020) investigated the EKC hypothesis in ten Middle-Income SSA countries between 1971 and 2012. The EKC theory is supported by the study's findings. Based on a country-specific examination, the EKC hypothesis has been validated in just three middle-lower income nations: Cote d'Ivoire, Kenya, and Nigeria; it was valid for Mauritius, South Africa, and Botswana in the middle-upper-income countries group.

Olubusoye & Musa (2020) examined the Environmental Kuznets Curve (EKC) hypothesis in 43 African nations pooled into 3 income groups from 1980–2016 using the ARDL model, Mean Group (MG), and the Pooled MG model. Just 21 percent of the sample accepts the EKC hypothesis, whereas 70 percent of the nations in the sample as a whole reject it. The findings indicate that in 79 percent of the nations, carbon emissions rise in tandem with economic expansion, whilst in just 21 percent of the countries does economic growth result in a decrease in carbon emissions. Consistent with the study's findings, most African nations would see increasing emissions as their economies expand.

Using the financial access, depth, and efficiency as supporting variables for financial development from 1987 to 2020, Ye et al. (2021) investigated the effects of financial development on environmental quality in Malaysia. To determine if there was a level relationship (long run) between the variables, the ARDL approach was applied. The factors were discovered to have a long-term association with environmental quality. In the medium and long terms, energy consumption, population expansion, economic growth, and financial development all positively and considerably contribute to environmental deterioration; in contrast, squared economic growth greatly improved environmental quality. Therefore, Malaysia's environmental Kuznets curve (EKC) is valid.

Geyikci, Çınar, & Sancak (2022) examined 13 developing nations' circumstances from 1993 to 2018. They came to the conclusion that energy usage, financial development, and economic expansion enhanced environmental dangers based on the use of the pooled mean group (PMG) approach. But using the same methodology, Mesagan, Vo, & Emmanuel (2022) shown that, in Africa, between 1990 and 2019, the integration of the financial sector marginally decreased short-term carbon emissions while dramatically increasing pollution over the long term.

Anwar et al. (2022) examined 15 Asian economies between 1990 and 2014 and shown how GDP growth, urbanization, and financial development all led to a rise in pollution. But they did find that using renewable energy reduced pollutants in the environment. Olaoye & Dauda (2022) researched on the impact of energy consumption, financial development, and carbon emissions on a subset of African nations from 1981 to 2019. Based on the framework of the co-integration regression approach, the study used FMOLS and DOLS to evaluate the panel data. The outcome shows that, in energy-dependent African nations, energy consumption has a positive and considerable impact on carbon emissions. Carbon emissions are directly impacted by financial development, and emissions of carbon are reduced as a result of financial development's mediating function between energy usage and carbon emissions.

Tinta (2022) examined the relationships that existed between economic growth, ecological transformation, and financial development in Sub-Saharan Africa between 1980 and 2019. A sample of 48 nations were subjected to the Dumitrescu and Hurlin causality tests, Pedroni and Westerlund cointegration, along with the Augmented Mean Group algorithm. The results corroborate the importance of human capital and institutional quality, but they only show an impact in high- and upper-middle-income nations. The degree of economic development is important, and human capital and renewable energy have an impact on the financial system's performance up to a certain point.

Based on data from 1990 to 2021, Saibu & Olagunju (2023) estimated two proxies of renewable energy using FMOLS second-generation cointegration and investigated the impact of education in advancing renewable energy in Nigeria. Additionally, by using actual economic growth and the import of fossil fuels as control in a model embedded with four education indicators, it tested the energy mix hypothesis in Nigeria and looked at how economic growth promotes education as a driver of energy transition. The findings demonstrated that Nigeria's aspirations for renewable energy depend heavily on education. The study found that, in contrast to previous research, education in all forms promotes Nigeria's transition from non-renewable to renewable energy use. In conclusion, purchasing power as quantified by economic growth is more significant than education for Nigeria's energy shift. Education, on the other hand, can minimize the negative consequences of economic expansion on energy shift capability.

The empirical literature reviewed illustrates paucity of empirical works on the link concerning energy use, financial development, economic growth, and carbon emissions especially within the West African sub-region. This study therefore is an attempt to fill this gap by using recent data to explore this link using the econometric approach of panel cointegration analysis based on the fully modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS).

METHODOLOGY

Model Specification

The model for this study is specified based on the environmental Kuznets curve (EKC) hypothesis, and the empirical works of Mesagan & Olunka (2020) and Olaoye & Dauda (2022). The model is therefore specified as follows:

$$CEM_{i,t} = f(RYH_{i,t}, RYH_{i,t}^2) \quad (3.1)$$

Where CEM is carbon emissions, RYH is the level of economic growth measured by the real income per capita, and $RYH_{i,t}^2$ is the squared of the RYH. Equation (3.1) is transformed into an estimable form as:

$$CEM_{i,t} = \beta_0 + \beta_1 RYH_{i,t} + \beta_2 RYH_{i,t}^2 + \mu_{i,t} \quad (3.1)'$$

Where i is the country, t is time, and μ is the error term. For the EKC hypothesis to hold, it is expected that $\beta_1 > 0$ and $\beta_2 < 0$.

By extending $(3.1)'$ to include key variables and to address the second objective of the study which is to ascertain the effect of financial development on carbon emission in West African economies, the model is specified as follows:

$$CEM_{i,t} = \beta_0 + \beta_1 RYH_{i,t} + \beta_2 RYH_{i,t}^2 + \beta_3 FDV_{i,t} + \beta_4 GCI_{i,t} + \beta_5 FDI_{i,t} + \beta_6 TRP_{i,t} + \mu_{i,t} \quad (3.2)$$

Where FDV captures finical development, GCI is the gross capital investment, FDI is foreign direct investment net inflows, and TRP is trade openness.

To model the interactive effect of financial development and economic growth on carbon emissions in West Africa, which is our third objective, the interactive model is specified as follows:

$$CEM_{i,t} = \beta_0 + \beta_1 RYH_{i,t} + \beta_2 RYH_{i,t}^2 + \beta_3 FDEG_{i,t} + \beta_4 GCI_{i,t} + \beta_5 FDI_{i,t} + \beta_6 TRP_{i,t} + \mu_{i,t} \quad (3.3)$$

Where $FDEG$ measures the interaction of financial sector development indicator with economic growth indicator.

Further, the model to ascertain the influence of energy utilization on carbon emissions in West Africa is presented below:

$$CEM_{i,t} = \beta_0 + \beta_1 RYH_{i,t} + \beta_2 RYH_{i,t}^2 + \beta_3 FDV_{i,t} + \beta_4 ENU_{i,t} + \beta_5 GCI_{i,t} + \beta_6 FDI_{i,t} + \beta_7 TRP_{i,t} + \mu_{i,t} \quad (3.4)$$

Where ENU is energy utilization and other variables in the model are as earlier defined.

In studying the mediating role of financial development in energy utilization on carbon emissions, the interactive model for the study is specified as follows:

$$CEM_{i,t} = \beta_0 + \beta_1 RYH_{i,t} + \beta_2 RYH_{i,t}^2 + \beta_3 FDEU_{i,t} + \beta_4 GCI_{i,t} + \beta_5 FDI_{i,t} + \beta_6 TRP_{i,t} + \mu_{i,t} \quad (3.5)$$

Where FDEU measures the interaction of energy utilization with financial sector development. Consistent with Equation (3.1) through Equation (3.5), the variables – carbon emission (CEM), real income per capita (RYH), real income per capita squared (RYH^2), and energy utilization (ENU) – are log-transformed to avoid biased estimates.

Description of Variables/Nature and Sources of Data

The description of the variables in the models is presented in Table 1 with the acronyms.

Table 1 Description of Variables

Variables	Definition	Description	Source
CEM	Carbon emission	Captured with carbon emissions (CO_2) measured in kilo tonnes	World Development Indicator, World Bank
RYH	Real income per head	Captured with GDP per capita – GDP per capita (constant 2015 US$)	World Development Indicator, World Bank
RYH^2	Real income per person squared	Captured with the square of Y to measure expansion in GDP as proposed by EKC	Computed by the Authors
ENU	Energy use	Captured with fossil fuel energy consumed per capita	World Development Indicator, World Bank
FDV	Financial Development	Captured with the available credits to the private sector (% of GDP)	World Development Indicator, World Bank
GCI	Gross Capital Investment	Proxied with gross capital formation	World Development Indicator, World Bank
FDI	Foreign direct investment	Captured with foreign direct investment net inflows (% of GDP)	World Development Indicator, World Bank
TRP	Trade Openness	Captured with trade in % of GDP	World Development Indicator, World Bank
FDEU	Financial development and Energy use interaction	Captured by multiplying financial development with energy utilization	Computed by the Authors
FDEG	Financial development and economic growth interaction	Captured by multiplying real GDP per capita by financial development indicator	Computed by the Authors

Source: Researchers' Compilation (2023)

The data utilized for this study are panel data which were obtained from the World Development Indicators which is a publication of the World Bank. The data covers two different time horizons: 1995 to 2022 and 1995 to 2014 due to the fact that data on energy utilization are available up to 2014 for most of the economies. The data were obtained from twelve (12) West African countries including Benin, Burkina Faso, Côte D'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

Technique of Analysis

This study utilized the homogenous unit root test developed by Levin, Lin, & Chu (2002) and the heterogeneous unit root test developed by Im, Pesaran, & Shin (2003) to ascertain the stationarity of the variables utilized in the study. This was followed by the use of the Kao Residual Cointegration test to ascertain whether a long-run relationship exists among variables in the model. The core analytical framework follows the cointegration regression analysis under the fully modified ordinary least squares (FMOLS) analysis. This technique is appropriate as it takes into consideration, any possible endogeneity and serial correlation which is highly pronounced in panel analysis involving long-run situations.

EMPIRICAL FINDINGS

Panel Unit Root Test

The homogenous (common) unit root test and the heterogenous (individual) unit root test respectively developed by Levin et al. (2002) and Im et al. (2003) are employed in this study, and Table 2 present the findings of the test.

Table 2 Panel unit root test result with data from 1995 - 2022

Variables	**Common Unit Root Process**				**Individual Unit Root Process**			
	Level		**First Difference**		**Level**		**First Difference**	
	Levin et al. (2002)	Probability	Levin et al. (2002)	Probability	Im et al. (2003)	Probability	Im et al. (2003)	Probability
CEM	-3.6853	0.0001*	-------	---------	-4.9963	0.0000*	--------	---------
RYH	2.4109	0.9920	-8.5737	0.0000*	2.59260	0.9952	-10.2268	0.0000*
RYH^2	2.3839	0.9914	-8.5156	0.0000*	2.4256	0.9924	-10.1577	0.0000*
FDV	-3.2079	0.0007*	---------	----------	-1.8340	0.0333*	-------	--------
FDEG	-2.8155	0.0024*	-14.5486	0.0000*	-1.4441	p0.0744	-14.6493	0.0000*
GCI	-1.0632	0.1439	-12.5652	0.0000*	-1.1775	0.1195	-13.6819	0.0000*
FDI	-2.4443	0.0073*	--------	---------	-2.1497	0.0158*	--------	-------
TRP	-1.9313	0.0267*	--------	--------	-3.7842	0.0001*	--------	-------

***Note*:** ** and * denotes significance at 1% and 5% respectively.
Source: Researchers' Computation (2023)

Consistent with Table 2, the homogenous unit root test result indicates that CEM, FDV, FDI and TRP were stationary at level. However, RYH, RYH^2, FDEG, and GCI became stationary upon first differencing. Under the heterogenous unit root test analysis, the result also presents a similar result of some of the variables being stationary at level and others being stationary at first difference. Consequently, we proceed to further estimations by checking on the existence of a long-run relationship in the model.
For the data set which covers the period 1995 to 2014, the unit root test result is presented in Table 3 for both the homogenous and the heterogenous test.

Table 3 Panel unit root test result with data from 1995 – 2014

Variables	**Common Unit Root Process**				**Individual Unit Root Process**			
	Level		**First Difference**		**Level**		**First Difference**	
	Levin et al. (2002)	Probability	Levin et al. (2002)	Probability	Im et al. (2003)	Probability	Im et al. (2003)	Probability
CEM	2.0204	0.9783	-3.68404	0.0001**	0.12761	0.5739	-8.13261	0.0000**
RYH	0.35295	0.6379	-2.15135	0.0157*	0.87586	0.8094	-2.53608	0.0056*
RYH2	0.32904	0.6289	-2.08875	0.0184*	0.86144	0.8055	-2.52553	0.0058*
FDV	-5.14312	0.0000**	--------	---------	-2.89804	0.0019*	--------	--------
ENU	-0.51942	0.3017	-8.16351	0.0000**	-0.95737	0.1692	-5.64599	0.0000**
FDEU	-4.22844	0.0000**	--------	--------	-2.08614	0.0185*	--------	-------
GCI	-0.10721	0.4573	-7.6491	0.0000**	0.46532	0.6791	-7.29129	0.0000**
FDI	-2.01913	0.0217*	--------	--------	-1.36869	0.0855	-5.10858	0.0000**
TRP	-3.46253	0.0003**	---------	---------	-3.70927	0.0001**	-------	--------

Note: ** and * denotes significance at 1% and 5% respectively.
Source: Researchers' Computation (2023)

From the result in Table 3 under the homogenous unit root test criteria, only FDV, FDEU, FDI, and TRP are reported to be stationary at level while all other variables are stationary at first difference. This same result is prevalent in the case of the heterogeneous unit root test result. Thus, we proceed to further estimations by checking on the existence of a long-run relationship in the model.

Panel Cointegration Test

The panel cointegration test is conducted through the use of the Kao residual cointegration test which generates the Augmented Dickey-Fuller (ADF) statistic. The result is presented in Table 4 for all the four models.

Table 4 Kao Residual Cointegration Result

Null: There is no Co-integration				
	Model 1	**Model II**	**Model III**	**Model IV**
	CEM and FDV Statistic	**CEM and FDEG Statistic**	**CEM and ENU Statistic**	**CEM and FDEU Statistic**
ADF	-7.2205 (0.0000)**	-6.9042 (0.0000)**	-3.5673 (0.0085)**	-4.6896 (0.0000)**
Residual variance	0.0191	0.0191	0.0262	0.0340
HAC variance	0.0234	0.0196	0.0257	0.0312

Note: ** denotes significance of the 1% level

Source: Researchers' Computation (2023)

Consistent with Table 5, the result for the three models indicates the significance of the ADF statistic at the 1% level of significance. This portrays the rejection of the null hypothesis, implying that there is cointegration in the four models.

Panel Cointegrating Regression Analysis

This study utilized cointegrating regression technique of regression analysis based on the fully modified ordinary least squares (*FMOLS*), and the dynamic ordinary least squares (DOLS) as a means of checking the robustness of the model. The results are presented based on the four models of the study.

Table 5 Fully Modified Least Squares Estimates for Model 1

Variable	Coefficient	Std. Error	t-Statistic	Probability
RYH	9.5276	2.0113	4.7370	0.0000**
RYH^2	-0.5753	0.1445	-3.9802	0.0001**
FDV	0.0231	0.0054	4.2540	0.0000**
GCI	0.0151	0.0041	3.6373	0.0003**
FDI	0.0108	0.0082	1.3145	0.1897
TRP	-0.0033	0.0022	-1.5026	0.1340
R-squared	0.9789	Mean dependent var		7.8519
Adjusted R-squared	0.9778	S.D. dependent var		1.6222
S.E. of regression	0.2420	Sum squared residual		17.9148
Long-run variance	0.1236			

Note: ** denotes significance of the 1% level

Source: Researchers' Computation (2023)

Table 5 presents the FMOLS regression for Model I where we explore the influence financial sector development on carbon emissions in West African countries. At first, the regression result reveal that the Environmental Kuznets Curve (EKC) hypothesis holds in Nigeria. This is derived from the fact that the coefficient of RYH is greater than zero and the coefficient of RYH^2 is less than zero, and both are statistically significant. Thus, there is a non-linear relationship between economic growth and carbon emissions in West Africa. Meanwhile, the implication of the result is that carbon emission increases as economic growth increases but starts to decline after a certain level of growth is achieved. The result further portrays that financial sector development exerts a positive and significant effect on carbon emissions in West Africa. Thus, a 1% increase in financial sector development will lead to a 000231% increase in carbon emissions on the average. The increasing financial sector development could ensure more credit to the private sector for expansion in production. Increased production may involve greater you of fossil energy which translates to greater carbon emissions within the region. Further findings from Table 5 indicates that gross capital formation (GCI) exerts a positive and significant effect on carbon emission, implying that a 1% increase in GCI will lead to a 0.0151% increase in carbon emissions on the average. Foreign direct investment (FDI) and trade openness (TRP) are both observed to exert an insignificant effect on carbon emissions in West Africa, with the effect of FDI being positive while that of TRP is negative. The explanatory variables jointly account for 97.89% of the total variations in carbon emissions in West Africa.

In order to ascertain the effect of financial development in economic growth on carbon emission in West African economies, Table 6 presents the FMOLS regression result.

The result in Table 6 still validates the Environmental Kuznets Curve (EKC) hypothesis in West Africa during the study period. By interacting financial sector development with economic growth (FDEG), the effect is observed to be positive and significant at the 1% level. This implies that financial sector development interacts with economic growth in increase the level of carbon emissions within the region. Thus, such interaction leads to a 0.0033% increase in carbon emissions within the region. Also, GCI is observed to exert a positive and significant effect on carbon emissions while both FDI and TRP exerted an insignificant effect. Thus, a 1% increase in GCI leads to a 0.0149% increase in carbon emissions when financial sector development interacts with economic growth. The explanatory variables jointly account for 97.89% of the total variations in carbon emissions in West Africa.

Table 6 Fully Modified Least Squares Estimates for Model II

Variable	Coefficient	Std. Error	t-Statistic	Probability
RYH	9.9187	2.0157	4.9207	0.0000**
RYH^2	-0.6057	0.1452	-4.1719	0.0000**
FDEG	0.0033	0.0008	4.2017	0.0000**
GCI	0.0149	0.0042	3.5965	0.0004**
FDI	0.0108	0.0082	1.3134	0.1900
TRP	-0.0032	0.0022	-1.4768	0.1408
R-squared	0.9789	Mean dependent var		7.8519
Adjusted R-squared	0.9777	S.D. dependent var		1.6222
S.E. of regression	0.2424	Sum squared residual		17.9737
Long-run variance	0.1238			

Note: ** denotes significance of the 1% level
Source: Researchers' Computation (2023)

To investigate the effect of energy utilization on carbon emission in energy-dependent West African countries, Table 7 presents the FMOLS regression result.

Table 7 Fully Modified Least Squares Estimates for Model III

Variable	Coefficient	Std. Error	t-Statistic	Probability
RYH	23.0809	7.6466	3.0184	0.0032**
RYH^2	-1.5318	0.5207	-2.9419	0.0040**
FDV	0.0243	0.0116	2.0933	0.0388*
ENU	0.8739	0.3231	2.7046	0.0080**
GCI	0.0042	0.0093	0.4554	0.6498
FDI	0.0424	0.0200	2.1228	0.0362*
TRP	-0.0037	0.0044	-0.8454	0.3999
R-squared	0.9701	Mean dependent var		8.8221
Adjusted R-squared	0.9665	S.D. dependent var		1.3357
S.E. of regression	0.2445	Sum squared residual		6.0356
Long-run variance	0.1029			

Note: ** and * denotes significance of the 1% and 5% level respectively.
Source: Researchers' Computation (2023)

The result in Table 7 also reflects the validity of the EKC Hypothesis when energy utilization is incorporated in the model. Financial sector development and foreign direct investment also exert positive and significant effect on carbon emissions. Energy utilization is observed to exert a positive and significant effect on carbon emissions as expected. Thus, a 1% increase in energy utilization results in a 0.8739% increase in carbon emission in West Africa. The model explains 97.01% of the total variation in carbon emission as reported by the R-squared.

By interacting energy utilization with financial sector development, Table 8 presents the empirical result obtained.

Table 8 Fully Modified Least Squares Estimates for Model IV

Variable	Coefficient	Std. Error	t-Statistic	Probability
RYH	19.5356	7.5059	2.6027	0.0106*
RYH^2	-1.2950	0.5118	-2.5304	0.0129*
FDEU	0.0062	0.0018	3.4908	0.0007**
GCI	0.0093	0.0093	0.9952	0.3220
FDI	0.0365	0.0200	1.8272	0.0706
TRP	-0.0051	0.0044	-1.1569	0.2500
R-squared	0.9662	Mean dependent var		8.8221
Adjusted R-squared	0.9625	S.D. dependent var		1.3357
S.E. of regression	0.2586	Sum squared residual		6.8211
Long-run variance	0.1051			

Note: ** and * denotes significance of the 1% and 5% level respectively.
Source: Researchers' Computation (2023)

In Table 8, the EKC hypothesis is still valid for West Africa when financial sector development is interacted with energy use. The interaction of financial sector development with energy use is observed to exert a positive and significant effect on carbon emission. Such interaction resulted in an increase in carbon emissions by 0.0062% on the average. The explanatory variables jointly explain 96.62% of the total variation in carbon emissions.

CONCLUSION

The issue of carbon intensity is a global concern given its impact green house and on sustainable environment. This is crucial because as the economy expands through increased production, there is likelihood for emissions to take place. This has led to the development of the environmental Kuznets curve hypothesis (EKC), which stipulates that there is an inverted U-shaped pattern of relationship between economic development and the environmental quality (Okijie & Effiong, 2021). When the EKC hypothesis is tested for the energy-dependent West African nations, the results from the FMOLS estimates of the four models demonstrate that the EKC preposition is valid for the countries since the corresponding models' coefficients of RYH are positive and their coefficients of RYH^2 are negative. This indicates that environmental quality continues to decline until a certain point, at which point it starts to recover, as long as economic growth continues. This contradicts the conclusions of Olaoye & Dauda (2022) and Mesagan & Olunkwa (2020). Nonetheless, our results concur with those of Okijie & Effiong (2021) and Ye et al. (2021). The findings therefore indicate that over time, firms will start to utilize clean energy in their course of production.

It has been noted that the development of the financial sector in West Africa significantly and positively affects carbon emissions. According to this result, the financial sector in the West African region seldom gives the eco-friendliness of the investments they are making a thorough consideration. The borrower's profile and the terms of credit repayment are essentially taken into account when funds are issued for investment. Once again, financial institutions in West African nations are motivated by profit and, as such, only lend money quickly for short-term investments, which may be inappropriate for promoting green investment. This is consistent with the empirical findings of Mesagan et al. (2022), Saud et al. (2019), Ehigiamusoe & Leon (2019), Tsaurai (2019), and Geyikci et al. (2022).

According to the findings again, there is a positive correlation between energy usage and carbon emission This indicates that the region's consumption of energy is endangering the environment. The evidence is not unexpected because these energy-dependent nations naturally possess abundant sources of massive energy, which they consume because it is deemed to be less expensive. Nigeria, for example, is the continent's greatest producer of crude oil, ranking 15th in the globe, and the 37th user of oil worldwide (Worldometre, 2020). This elucidates the region's noteworthy and affirmative influence on energy consumption and carbon emissions. The result is further supported by the fact that this region of the world is still in the early stages of the energy source transition effort. Consistent with Geyikci et al. (2022), Mesagan & Olunkwa (2020), Ehigiamusoe & Leon (2019), and Ye et al. (2021), the result is comparable.

The results showed that, in energy-dependent African countries, the interactive effect of financial development cum energy utilization causes carbon emission to increase by approximately 0.0062% for every 1% change, indicating the facilitating role of financial development in the relationship concerning energy utilization and carbon emission. The interaction impact is interestingly statistically significant at the 1% level. The result presented here demonstrates that the West African financial sector is unable to promote environmental sustainability by investing in clean energy, which is essential for cutting greenhouse gas emissions. These results contradict those of Kwakwa (2019), who found conflicting data for Ghana by examining the association between energy usage and financial development. In conclusion, the financial sector in the West African region seldom gives the eco-friendliness of the investments they are making a thorough consideration, and financial institutions in West African nations are motivated by profit and, as such, only lend money quickly for short-term investments, which may be inappropriate for promoting green investment.

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TRANSPARENCY

The authors hereby declare that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study cited all relevant sources and utilized data from reliable sources.

DATA AVAILABILITY STATEMENT

The corresponding author may provide study data upon reasonable request.

COMPETING INTERESTS

The authors hereby declare that they have no competing interests in any form.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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