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ENERGY USE, FINANCIAL DEVELOPMENT AND POLLUTION IN SELECTED AFRICAN COUNTRIES

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ABSTRACT

The consequences of environmental pollution on human life have continued to exacerbate in recent times, especially in African countries. This has spurred research interest among researchers to find out how nations can keep carbon emissions in check. In this regard, this study focuses on some selected African countries between 1981 and 2019 to investigate the effect of energy use, financial development and carbon emission. The study employs the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) based on the framework of the co-integration regression method to analyze the panel data. The result reveals that energy use positively and significantly affects carbon emissions in energy-dependent African countries. Financial development positively affects carbon emissions, while the mediating role of financial development between energy use and carbon emission causes carbon emissions to reduce. Therefore, the study recommends that energy-dependent African countries strengthen their financial sector to ensure credit availability for green supportive investment.

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INTRODUCTION

In the environmental economics literature, a high level of carbon emissions has often been traced to economic growth. Studies believe that the quest to expedite growth goes together with increasing the volume of CO_2 emissions that are generated and discharged in the atmosphere frequently, more especially during production activities. Moreover, such a rise in CO2 emissions can emanate from the need for housing and food production due to rising population density that necessitates the depletion of the environment through the felling of trees and overall biodiversity degradation to make room for the growing population (Asafu-Adjaye, 2003). In the same vein, it is expected that environmental quality degrades as economies witness expansion in economic activities owing to the rise in Gross Domestic Product (GDP). This is because the rise in GDP is necessitated by expansion in economic productivity, which is mostly driven by unsustainable energy sources like coal, fossil fuel and nuclear energy. With the quest to converge and catch up with developed economies, developing economies, most especially energy-dependent African economies, are at risk of environmental degradation due to the utilization of dirty energy sources that they considered being cheaper in propelling economic activities (Omojolaibi et al., 2016; Mesagan and Olunkwa, 2020).

On the forgoing, the assertion follows the proposition of the Environmental Kuznet Curve. The proposition posits that at the early stage of economic growth, growth is accompanied by higher environmental pollution as the level of carbon emissions associated with industrial effluents discharged by industries increases. However, as the economy can achieve its growth target, they put measures to control pollution in place. Further increase in economic growth is accompanied by lower environmental pollution and higher environmental quality (Stern, 2004; Ajide and Mesagan, 2022; Tabash et al., 2022). However, in recent times, scholars such as Atanda et al. (2017), Lu (2018), Anwar et al. (2022), and Evans and Mesagan (2022) have shifted from output growth criteria by considering other factor determinants such as energy consumption behaviour, trade volume, income, capital investment, financial development among others. Empirical findings in this regard had been conflicting due to the differences in data types (time-series, cross-sectional and panel) and econometrics techniques employed (Mesagan and Olunkwa, 2020; Tsaurai, 2019; Lu, 2018; Nasreen et al., 2017; Sadorsky, 2011; Basarir and Cakir, 2015; Li et al., 2017; Mesagan et al., 2018).

In this regard, the main thrust of this study is to explore the mediating role of financial development in energy use and carbon emission nexus in Africa. Specifically, we analyze the effect of energy consumption on carbon emissions. The study also assesses the effect of financial development on carbon emissions in selected energy-dependent African nations. And lastly, we interact with energy consumption and the financial sector to analyze the mediating impact of financial development on carbon emission via energy use. However, this present study departs from the existing literature by incorporating financial development as a mediating factor in energy use and the CO2 emission model. This is due to the fact that the financial sector mobilizes and channels financial resources towards economic productivity. Meaning that the financial sector can mediate in channelling funds in the direction of investment that is energy friendly which consequently engenders the use of environmentally friendly energy sources, which in the end, improves environmental quality and economic progress. Therefore, the pace of energy consumption, financial development, and the quest to catch up with economic development in energy-dependent African economies such as Nigeria, Tunisia, Egypt, Morocco, and Algeria1 call for concern about the environmental effect of such fast pace growth. Again, the fact that African countries are fast gaining prominence in carbon monoxide contribution globally and are often witnessing environmental degradation. Additionally, these countries have the largest banking sector in Africa. According to Statista (2022), with aggregate tier 1 capital of $24,321, $17,706, $13,038, and $11,444 as of 2021, Egypt, Morocco, Nigeria, and Algeria are among the top five leading countries in the banking sector in Africa. This denotes that the selected nations have a massive financial system; thus, it is crucial to analyze the sector's role in environmental sustainability in Africa (Mesagan et al., 2022a,b,c). Methodologically, the study adopts the cointegrating regression technique vis-à-vis fully modified and dynamic ordinary least squares to analyze the connection between energy consumption, financial development and carbon emission in Africa. This estimation technique allows us to adjust the standard pooled OLS for serial correlation and endogenous regressors, which are typically present in a long-term relationship, thus producing reliable long-run estimates to support policy decisions for Africa. Therefore, the remaining parts of the paper follow; 2. Literature review, 3. Methodology, 4. Presentation and discussion of findings, and 5. Conclusion and policy recommendation.

LITERATURE OF REVIEW

In this section, various empirical studies that are related are discussed. For instance, Kahouli (2017) analyzed the situation in six southern Mediterranean countries and found that a long-run relationship existed between the income, financial sector and output for all countries except Egypt. Abid (2017) found a monotonically rising nexus between income and output growth in Africa, the Middle East, and the EU nations over the period between 1990 and 2011. Again, Bekhet et al. (2017) confirmed that financial development unidirectionally caused CO_2 emissions in the UAE, Oman and Kuwait. Also, Nasreen et al. (2017) focused on the Asian economies. They found that the financial sector has a negative impact on pollution, while income and energy use increased CO2 emissions among the sample of countries. Also, Maji et al. (2017) found that the financial sector did not intensify pollution in both oil & gas, while it reduced pollution in the manufacturing and construction sectors in Malaysia.

Li et al. (2017) investigated a similar situation in China between 1965 and 2015. Findings revealed the feedback effect between coal use and income, gas use and income, and pollution and coal usage. However, oil and gas usage and income unidirectionally caused pollution, while coal usage has a unidirectional link with gas consumption. In a similar study by Shahbaz et al. (2017), no causal relationship was found between financial development and energy use, while both indicators exerted a negative influence on economic growth in India. Mesagan and Nwachukwu (2018) analyzed the situation in Nigeria between 1981 and 2016. The study found no causality between capital investment, financial development and environmental quality, while urbanization and income unidirectionally cause environmental degradation. They also found bidirectional causality between pollution and energy consumption, thereby calling for investment in clean technologies. Lu (2018) focused on twelve (12) Asian economies from 1993 to 2013 using the Pedroni method of panel co-integration and found that economic growth, ICT and energy consumption are cointegrated in the long run while economic growth and energy consumption have a positive effect on carbon emission, but a negative nexus was found between ICT and carbon emission.

Again, Saud et al. (2019) extended the study to 18 Eastern and Central European nations between 1980 and 2016. Findings revealed that (i) income and finance further deepened environmental degradation; (ii) energy use substantially drove pollution; (iii) trade and urbanization improved the environment; and (iv) the EKC proposition was also confirmed. The causality analysis revealed a mutual relationship between pollution and income and energy use, and financial development. Tsaurai (2019) employed the panel OLS estimation technique to analyze financial development and pollution in West African countries between 2003 and 2014. The study revealed that financial development in the region worsens pollution. Ehigiamusoe and Leon (2019) conducted a wide range of studies on financial development, economic growth and energy consumption and carbon emission for 122 economies using the 1st and 2nd generation panel co-integration and estimation method between 1990 and 2014. The study revealed that financial development, economic growth and energy consumption triggered a rise in carbon emissions. It disaggregates the panel into high-income, middle, and low-income countries. The study revealed that financial development and economic growth decoupled carbon emissions in high-income countries, while the reverse is the case for middle and low-income countries. More so, Kwakwa (2019) conducted a similar study for Ghana between 1971 and 2014. The study interacted with financial development and energy to ascertain the mediating impact of financial development on carbon emission. Based on the ARDL methodology and FMOLS, the study revealed that financial development and energy use interaction reduced carbon emissions in Ghana.

For African countries, Mesagan and Olunka (2020) examined capital investment, energy consumption and environmental pollution using the co-integration regression method (FMOLS and DOLS) between 1981 and 2017. The result revealed that capital investment and energy consumption positively affect environmental pollution in Africa, respectively. And capital investment was found to be a mediating factor for energy consumption in reducing environmental pollution in Africa.

Rafique et al. (2020) provided evidence from BRICS from 1990 and 2017 using the Augmented Mean Group. The study revealed that technological innovation, FDI and financial development reduced CO2 emissions in the long run. Similarly, Shoaib et al. (2020) conducted a comparative study of D8 and G8 economies from 1999 to 2013. The study employed the pool Mean Group technique to analyze the panel series. The result revealed that financial development and energy use worsen carbon emissions in both D8 and G8 economies. Geyikci et al. (2022) considered the situation of 13 developing countries between 1993 and 2018. Based on the adoption of the PMG technique, they concluded that energy use, financial development and economic growth promoted environmental hazards. However, with the same method, Mesagan et al. (2022a) showed that the financial sector integration insignificantly reduced short-run carbon emissions but magnified pollution substantially in the long run in Africa between 1990 and 2019. Lastly, Anwar et al. (2022) focused on 15 Asian economies between 1990 and 2014 and showed that financial development, urban growth and GDP expansion increased pollution. However, they established that renewable energy use curtailed environmental pollution.

Owing to the presented evidence, Bekhet et al. (2017), Nasreen et al. (2017), Maji et al. (2017), Saud et al. (2019), Tsaurai (2019), Ehigiamusoe and Leon (2019), Shoaib et al. (2020), Rafique et al. (2020), Geyikci et al. (2022), and Anwar et al. (2022) incorporated financial development in the energy use and carbon emission model, but in this present study, we interact financial development and energy use to ascertain the mediating role of financial development in the energy use and CO2 emission model like Kwakwa (2019. However, unlike Kwakwa (2019) the focused on Ghana, our study considers a panel of energy-dependent African countries to ascertain the joint effect of these countries on pollution reduction via the financial sector. Therefore, the study made a modest contribution to the body of knowledge considering five energy-dependent African countries, i.e. Nigeria, Tunisia, Egypt, Morocco and Algeria. These countries rely on energy resources such as crude oil, coal and natural gas to promote industrialization and also a source of foreign earnings. For example, about 95% of Nigeria's foreign earns are from the exploration and exportation of crude oil. More so, In terms of the financial sector, these countries have the largest banking sector. According to Statista (2022), with total tier 1 capital of $24,321, $17,706, $13,038, and $11,444 as of 2021, Egypt, Morocco, Nigeria, and Algeria are among the top five leading countries in the banking sector in Africa. The size of the financial market and its dependence on energy resources motivates the study to analyze the role the financial sector can play in mitigating climate change in Africa via energy consumption. This is innovative as this nature of study for energy-dependent African countries is very scarce. In terms of methodology, the study uses panel co-integration techniques vis-à-vis the fully modified and dynamic OLS approaches. The methods allow us to adjust the standard pooled OLS for serial correlation and endogenous regressors, which are typically present in a long-term relationship, thus producing reliable long-run estimates to guide pollution reduction policy for African countries. Hence, the novelty of this study.

METHODOLOGY

This study employed the Cointegrating regression based on the framework of Fully Modified Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS), as suggested by Pedroni (2001). This is because the technique considers the possible care of endogeneity and serial correlation problems that naturally plague panel analysis in a long-run relationship. However, we utilize the DOLS as an alternative method which offers a computationally convenient alternative to the panel fully modified OLS. However, unlike the FMOLS, the DOLS is a parametric technique that utilizes leads and lags of differentiable regressors to get rid of serial correlation and endogeneity (Ullah et al., 2020). Additionally, the DOLS addresses small sample biases (Mesagan and Olunka, 2020). Hence, we employ the DOLS estimator as an alternative technique to check the robustness of FMOLS.

Therefore, the model for this study leans on the EKC hypothesis and the empirical studies of Mesagan and Olunka (2020) and Ehigiamusoe and Leon (2019). The model becomes as:

$$CO2_{it} = \phi_0 + \phi_1 Y_{it} + \phi_2 Y_{it}^2 + \varepsilon_{it} \quad (1)$$

Equation (1) is the EKC model in which carbon emission (CO_2) is the dependent variable in this study. The EKC model depicts an inverse relationship between pollution and income. ϕ_1 It is expected to be positive while ϕ_2 will be negative. 'i' is the number of countries, 't' is the time series, and 'ε' is the residual term.

In this study, equation (1) is extended by incorporating other variables following the objectives of the study to accommodate fossil fuel energy use (EN) per person (Farhani and Ben Rejeb, 2012). Also, financial development (FD) is brought into the model. Again, foreign direct investment (FDI), gross investment (CI), and trade openness (TO) are controlled variables. Thus, the models are as follows:

$$CO2_{it} = \phi_0 + \phi_1 Y_{it} + \phi_2 Y_{it}^2 + \phi_3 EN_{it} + \phi_4 CI_{it} + \phi_5 FDI_{it} + \phi_6 TO_{it} + \varepsilon_{it} \quad (2)$$

Equation (2) captured the fossil fuel energy use and carbon emission linkage in energy-dependent African economies.

$$CO2_{it} = \phi_0 + \phi_1 Y_{it} + \phi_2 Y_{it}^2 + \phi_3 FD_{it} + \phi_4 CI_{it} + \phi_5 FDI_{it} + \phi_6 TO_{it} + \varepsilon_{it} \quad (3)$$

Equation (3) captured the effect of financial development on carbon emission linkage in energy-dependent African economies.

$$CO2_{it} = \phi_0 + \phi_1 Y_{it} + \phi_2 Y_{it}^2 + \phi_3 FDEN_{it} + \phi_4 CI_{it} + \phi_5 FDI_{it} + \phi_6 TO_{it} + \varepsilon_{it} \quad (4)$$

While equation (4) captured the mediating role of financial development in energy use and carbon emission in energy-dependent countries, equation (2), (3) and (4) ϕ_0 is the intercept term, while $\phi_1, \phi_2, \phi_3, \phi_4, \phi_5, \phi_6$ are the coefficients of the various explanatory variables as defined. If ϕ_1 >0 and ϕ_2 <0, the EKC proposition exists in Africa. Similarly, Energy use (EN), Real income per person squared (Y^2), Carbon emission (CO_2) and financial development and Energy use interaction (FDEN) are log transformed to prevent bias estimate since variables are in their natural form. Furthermore, the study selects five energy-dependent countries for analysis, i.e. Nigeria, Tunisia, Egypt, Morocco and Algeria. These nations were sampled for this study because they serve as examples of African nations that largely rely on energy to drive modernization and generate foreign earnings. For instance, crude oil accounts for about 95% of Nigeria's foreign exchange (Olayungbo & Adediran, 2017). Crude oil and natural gas account for about 49.5% and 50.4% of the energy source in Algeria and are also the third largest producer of crude oil (IEA, 2019). Hence, it is pertinent to understudy these nations' carbon footprint and their financial sector's role in lowering carbon discharge. Therefore, the data used for analysis are summarised in Table 1.

Table 1. Data source and description.

Variables	Definition	Description	Data Source
CO2	Carbon emission	captured with carbon emissions (CO2) measured in kilo tonnes	World development Indicator, 2020
Y	Real income per person	Captured with GDP per capital	World development Indicator, 2020
Y2	Real income per person squared	Captured with the square of Y to measure expansion in GDP as proposed by EKC	Derived
EN	Energy use	Captured with fossil fuel energy consumed per capita (EN)	World development Indicator, 2020
FD	Financial Development	Captured with the available credits to the private sector	World development Indicator, 2020
CI	Gross Capital Investment	Proxied with gross capital formation	World development Indicator, 2020
FDI	Foreign direct investment	Captured with foreign direct investment net inflows	World development Indicator, 2020
TO	Trade Openness	Captured with trade in % of GDP	World development Indicator, 2020
FDEN	Financial development and Energy use interaction	Captured with financial development and energy use interaction	Derived

Note: The table is compiled by author and the list of countries for analysis are Nigeria, Tunisia, Egypt, Morocco and Algeria are selected for the study.

EMPIRICAL RESULT

Panel Unit Root Test

This study employed the homogeneous (Levin et al., 2002 and Breitung, 2001) and heterogeneous (Im et al., 2003 and ADF–Fisher) panel unit root criteria, and the result is presented in Table 2. A cursory look at Table 2 shows that all the variables are not stationary for both homogeneous and heterogeneous panel unit root criteria. However, at 1st difference, all the variables are stationary for both homogeneous and heterogeneous panel unit root criteria. This implies that the evidence refutes the null hypothesis that the variables are not stationary. Therefore, the study proceeds to further estimation.

Panel Co-integration Test

The study presents a co-integration test using the Kao residual co-integration. The test shows the long-run relationship among the variables and the result of Kao residual co-integration result based on the estimated models, which includes; energy use and CO2 emission nexus (EN and CO2), financial development and CO2 emission (FD and CO2) and the mediating role of financial development in energy use and carbon emission (FDEN and CO2) in Table 3.

Table 3 presents the Kao residual co-integration results for the estimated models. The results show a co-integration among the panel series at a 1% significant level. This means that there is co-integration among the vectors and thus denotes the rejection of the null hypothesis that there is no co-integration.

Presentation of Cointegrating Regression Result

The study employed the cointegrating regression technique of regression using the FMOLS and DOLS to estimate the panel regression. The results for the cointegrating vectors for both FMOLS and DOLS are presented in Table 4 and 5, respectively.

Table 2. Panel Unit Root Result.

Variables	Homogeneous unit root				Heterogeneous unit root			
	Level		1st difference		Level		1st difference	
	Levin et al (2002)	Breitung (2001)	Levin et al. (2002)	Breitung (2001)	Im et al. (2003)	ADF–Fisher	Im et al. (2003)	ADF–Fisher
CO_2	-3.2805***	5.4147	-6.1490***	-5.1748***	0.1450	-0.8640	-9.0173***	52.225***
Y	0.2679	1.5501	-5.0961***	-5.9331***	2.4644	-1.8669	-6.1671***	18.193***
Y^2	-0.4019	1.9493	-4.4958***	-5.6898***	1.9482	-1.7970	-6.2891***	18.442***
EN	-0.7304	0.9117	-6.2855***	-4.5046***	-0.6142	-0.2130	-8.4085***	40.169***
FD	-0.7740	-1.2966	-4.5070***	-6.6060***	0.5699	-0.9341	-6.5491***	21.683***
CI	-2.8002***	0.2986	-7.8838***	-7.6514***	-1.3609*	1.8517**	-7.6106***	30.996***
FDI	-3.1275	-4.6395***	-7.2284***	-7.1093***	-4.2351***	9.2937***	-9.3897***	58.061***
TO	-0.7531	-1.5065**	-8.0489***	-6.3413***	-0.6470	0.5684	-7.7763***	33.849***
FDEN	-0.8886	-0.8452	-5.6536***	-7.7804***	0.0637	-0.4993	-7.3439***	27.379***

Source: Author's Computation using STATA 15; *** and ** represent 1% and 5% level of significance.

Table 3. Kao Residual Cointegration Result.

Null: There is no Co-integration			
	En and CO2 Statistic	FD and CO2 Statistic	FDEN and CO2 Statistic
ADF	-2.2042***	-2.484403***	-2.435406***
Residual variance	0.001306	0.001311	0.001312
HAC variance	0.001068	0.001198	0.001182

Source: Author's Computation using Eviews 9; where *** represent 1% level of significance.

Table 4. Fully Modified Ordinary Least Squares (FMOLS) Estimate.

Regressors	En and CO2	FD and CO2	FDEN and CO2
	0.00003	0.00008***	0.00007**
Yx	(0.00002)	(0.00002)	(0.00002)
	0.0799	0.0645	0.0880
Y2	(0.0542)	(1.2509)	(0.0611)
	0.9145***	-	-
EN	(0.1627)		
	-	0.0007	-
FD		(0.0004)	
	-	-	-0.0211**
FDEN			(0.0092)
	-0.0004	0.00006	-0.0002
TO	(0.0009)	(0.00104)	(0.0010)
FDI	0.0156***	0.0235***	0.0234***
	(0.0062)	(0.0071)	(0.0068)
CI	-0.0015	-0.0013	-0.0013
	(0.0010)	(0.0012)	(0.0011)
R-Squared	0.9531	0.9382	0.9392
Adj R-Squared	0.9505	0.9348	0.9358

Source: Author's Computation using Eviews 9; *** and ** represent 1% and 5% level of significance.

Table 4 present the FMOLS estimates for the cointegrating vectors in line with the stated objectives of the study. For the energy use and CO2 emission (En and CO2) model, the estimate shows that energy use positively relates to carbon emission. Such that as energy use rises by 1%, carbon emission rises by about 91.4% in energy-dependent African countries. This means that energy use in the region put the environment in danger. The evidence is not surprising owing to the fact that these energy-dependent countries are naturally endowed with thick energy sources and consequently utilize such as it is considered cheaper to use. For instance, Nigeria is the 15th largest crude oil producer globally and Africa's largest oil producer (Worldometre, 2020). This explains the region's positive and significant impact on energy use and carbon emission. Similarly, the energy source transition campaign in this part of the world is still at its rudiment and thus also justifies the evidence. The result is similar to the findings of Geyikci et al. (2022), Mesagan and Olunkwa (2020), Ehigiamusoe and Leon (2019).

Further, the evidence on financial development and C02 emission revealed that financial development causes CO2 emissions to rise. In that, as financial development rises by at least 1%, environmental pollution through CO2 emission in the region rises by about 0.07%. However, the coefficient is not statistically significant. This evidence implies that the financial sector in the region seldom considers the environmental friendliness of the investment they are channelling resources to. What is basically considered in the issuance of funds for investment is the profile of the borrower as well as the credit repayment condition. Again, financial institutions in African countries are profit driven and, as such only swift in issuing short-term funds for investment which is not appropriate for driving green investment. This resonates with the empirical evidence of Saud et al. (2019), Ehigiamusoe and Leon (2019), Geyikci et al. (2022) and Mesagan et al. (2022b).

In the same vein, to ascertain the mediating role of financial development in the link between energy use and CO2 emission in energy-dependent African countries, the result revealed that the interactive effect of financial development and energy use triggers CO2 emission to decline by about 2.1% in every 1% change. Interestingly, the interactive effect is statistically significant at 5% level. This evidence shows that the financial sector is potent in driving a sustainable environment through the channelling of financial resources to investments that support environmentally friendly energy, which is pivotal in reducing greenhouse gas emissions. Interestingly, Kwakwa (2019) found similar evidence for Ghana by interacting with financial development and energy consumption.

Testing the EKC proposition for the energy-dependent African, evidence from FMOLS estimate from the three models shows that the EKC preposition does not hold for the countries as both coefficients of Y and Y^2 for the respective models are all positive. This means that as economic growth continues to increase, environmental quality continues to deteriorate. Mesagan and Olunkwa (2020) found similar evidence for African countries.

Table 5. Dynamic Ordinary Least Squares (DOLS) Estimate.

Regressors	En and CO2	FD and CO2	FDEN and CO2
	0.00004	0.0001**	0.000137***
Y	(0.00003)	(0.00004)	(0.00004)
	0.1059	-0.0348	-0.0660
Y2	(0.0714)	(0.1064)	(0.1010)
	0.4712**	-	-
EN	(0.2492)		
	-	0.0012	-
FD		(0.0007)	
	-	-	-0.0397***
FDEN			(0.0156)
	0.00004	-0.0019	-0.0023
TO	(0.0014)	(0.0024)	(0.0023)
FDI	0.0479***	0.0525***	0.0405***
	(0.0128)	(0.0176)	(0.0149)
CI	0.0004	-0.0019	-0.0025
	(0.0017)	(0.0023)	(0.0022)
R-Squared	0.9848	0.9764	0.9792
Adj R-Squared	0.9656	0.9467	0.9530

Source: Author's Computation using Eviews 9 where *** and ** represent 1% and 5% level of significance.

In Table 5, the study presents the Dynamic Ordinary Least Squares estimates for the cointegrating vectors. For energy use and CO2 emission nexus, the result reveals that energy use in energy-dependent countries degrades the environment since energy use positively and significantly impacts CO2 emission. As the coefficient of energy use is 0.4712, it denotes that as the value increases by at least 1%, CO2 emission rises by 47.1%. Again, the evidence for financial development and CO2 emission shows that financial development positively relates to carbon emission in energy-dependent African economies. The possibility of the evidence is not surprising as the financial sector in the region is still developing, and they are more convenient in driving short-term investment. Those kinds of funds cannot drive sustainable investment that can expedite environmental quality.

Again, the evidence on the mediating role of financial development in energy use and carbon emission linkage shows that financial development is significant in driving environment quality by reducing the level of carbon emission-funded investment. This is because the evidence reveals that the interacting variables (FDEN) are negatively related to CO2 emission with a coefficient of -0.0397. This means that as the variable changes by 1%, CO2 emission reduces by 3.9%, which is significant at 1%. On the foregoing, the evidence of DOLS estimate for the cointegrating vectors, as presented in Table 5, resonates with that of FMOLS estimates presented in Table 4. This means that the DOLS estimate validates the robustness of the FMOLS estimates. However, the point of departure is that ascertain the validity of EKC for the countries' DOLS estimate, refute the preposition for energy use and carbon emission while the EKC proposition is valid for the countries as financial development is regressed on carbon emission and as well as when it interacts with energy use. This means that financial development plays a pivotal role in accelerating economic growth and as well as reducing the environmental pollution in energy-dependent African countries. And consequently, validates the EKC preposition.

Diagnostic Test

The study checked whether the estimated vector residuals are normally distributed using the normality test diagnostic. This is because the non-normally distributed residual is a pointer to the true robustness of the regression estimates. Hence, this study use histogram and the Jarque-Bera normality test to check whether the residuals are normally distributed (Figure 1, 2 and 3).

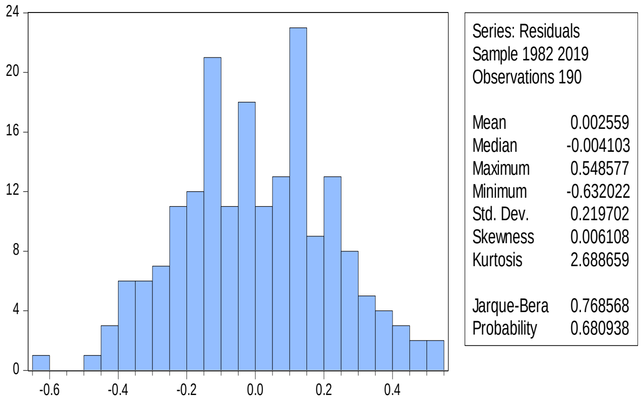

Figure 1. Energy use and CO2 Emission.

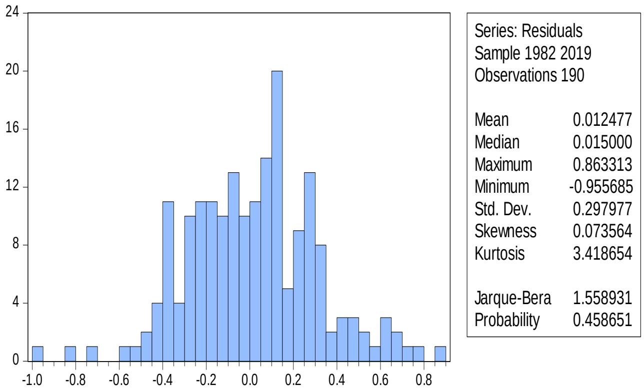

Figure 2. Financial Development and CO2 Emission.

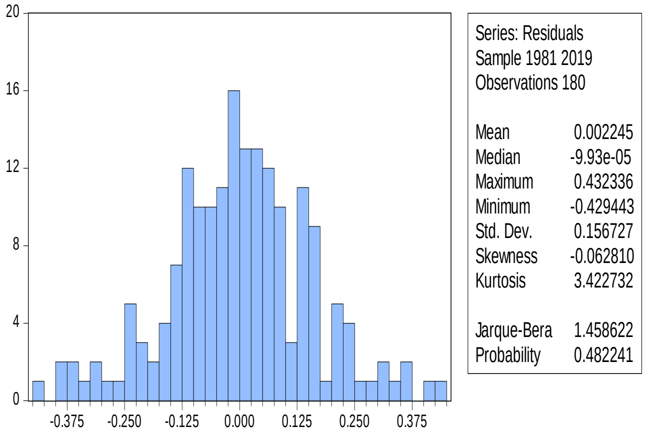

Figure 3. Interactive effect of Energy use and Financial Development on Emission.

In Figures 1, 2 and 3, the study presents the histogram and JB statistic, among others. The histograms suggest that the residuals are normally distributed, and JB probability further confirms the normality of the histogram. Therefore, since the JB probability is greater than 5%, as shown in Figure 1, 2 and 3, the study rejects the alternative hypothesis that the residuals are not normally distributed and conclude in favour of the null hypothesis that the distribution is normal. The implication is that there is no problem of unequal variance in the panel series since the residuals are normally distributed.

CONCLUSIONS AND RECOMMENDATIONS

This study investigates energy use, financial development and carbon emission in some selected energy-dependent African economies from 1981 and 2019. The study employs the co-integration approach to regression using the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) to analyze the panel. Both FMOLS and DOLS results reveal that energy use positively and significantly affects carbon emissions in energy-dependent African economies. The evidence is not surprising because most energy-dependent African countries are naturally rich in thick energy sources and consider it cheaper to use than environment-friendly energy. Again, FMOLS and DOLS estimates show that financial development worsens carbon emissions in selected energy-dependent African economies. Meaning that as financial development rises, carbon emission rises as well. This is because the financial sector is not yet developed in this part of the world, so it is convenient to fund investments that can yield returns in short-term periods. Most environment-friendly investments require a long-term gestation period. Checking the mediating role of financial development in the nexus between energy use and carbon emission, both FMOLS and DOLS estimate reveals that financial development is potent in mediating between energy use and carbon emission. This means that the financial sector can drive environmental quality by making funds available to investors investing in green projects. Lastly, for the three estimated models, the EKC proposition does not hold for the countries based on FMOLs estimate, but for DOLS the EKC proposition holds for the countries when financial development is regressed on carbon emission and when it interacts with energy use. Owing to this, energy-dependent African countries should strengthen their financial sector to make credit facilities available to investors investing in green energy, supporting investment to keep environmental pollution through CO2 emission in check. This can be achieved by strengthening the market through regulation to monitor the credit flow of the financial market. Further, energy-dependent African countries should restrict the amount of funds flowing through the financial sector to non-environmentally compliant investment through restrictive policies. Therefore, this is achievable through sector-specific credit regulations. By this, the financial sector will be mandated to prioritize clean energy investment in creating credit facilities. However, despite the novelty of this study, it is not without some caveats. For instance, the study focuses on five energy-dependent African countries out of 54 African countries. The study's findings are limited to the selected countries as the findings do not capture the entire population (Africa). Future studies may expand the scope of this study to capture the entire 54 countries broadly. Also, the size of the financial market of these countries is not the same, although they have large financial sectors. Therefore, our study is limited to the joint findings of the effect of the financial sector on pollution control. Hence, future studies may attempt to conduct a time series analysis regarding this.

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