Examining the Role of Trade on the Relationship between Environmental Quality and Energy Consumption: Insights from Sub-Saharan Africa

Abstract

This study looks at the relationship between energy consumption and environmental quality in Sub-Saharan Africa (SSA) and how trade with other countries affects it. It examines data from 35 SSA economies between 1996 and 2020, categorized into low-income (LICs) and middle-income (MIC) countries. Using the cross-sectional augmented autoregressive distributed lag (CS-ARDL) approach, the results show that energy use, especially in MICs, negatively affects environmental quality. Trade, however, considerably lessens these detrimental environmental implications of energy consumption. According to the study, legislative actions intended to stop environmental deterioration in Sub-Saharan Africa should take into account the unique political and economic circumstances of each country. In addition, authorities should strike a balance between economic interests and environmental concerns, particularly in sectors dependent on the importation of used goods, and trade and environmental regulatory agencies must work together to enforce age restrictions on imported used items.

JEL Classifications :Q43, F13, C23, Q58

Keywords: Energy Use, Environmental Quality, Trade, CS_ARDL, AfCFTA

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1.0 Introduction

One of the most significant issues facing both developing and industrialized nations worldwide is the climate change. As the state of the earth continues to deteriorate, governments, international organizations, corporate groups, and academia appear to have all begun to pay attention to this growing crisis. **Akadiri et al. (2019**) claim that emissions of CO_2 are to blame for this damage. Similarly, economic activities are typically to blame for high levels of carbon emissions, according to **Eregha & Mesagan (2017).** The type and quantity of products and services an economy creates and consumes determine its rate of growth. To make a living, there is always a tendency to produce and market as the standard of living is heavily influenced by the commodities and services that are made available to the populace in society at large. Growth also has a development component that makes equal distribution feasible. In order to do this, products must be transported around the globe. To improve the quality of livelihoods, products, particularly in the manufacturing sector, are exported from one nation to another**(Mesagan et al., 2022).** The majority of the commodities and services imported by developing countries come from the industrialized countries. As a result, Sub-Saharan Africa (SSA) has witnessed an unprecedented increase in the tendency of importing both new and second-hand goods from these countries since the late 1980s, partly for consumption and industrial uptake.

Asserting a link between economic activity and environmental quality are **Faruq (2023**), **Ahmad & Du (2017**), **Padhan et al. (2019), Kahia et al. (2019), and Ahmad & Du (2019).**This implies that attempts to promote economic growth, particularly through industrial and manufacturing activities, are linked to an increase in energy consumption, which fuels carbon emissions, which in turn degrades environmental quality. The reason for this is that SSA economies are largely dependent on technologies that use energy sources like coal, gas, and fossil fuels, which are perceived to be less expensive to consume yet with high negative environmental effects, in their efforts to promote economic expansion. This reasoning is in line with the first-order condition of the Kuznet Curve (EKC) of environment, which holds that as the economy expands, carbon emissions increase and have a detrimental effect on the environment. Unfortunately, the majority of the world's economies, especially the SSA, are not affluent enough to use less carbon-emitting (energy-efficient) technologies to drive their growth expansion-drive.

More specifically, it is crucial to understand how environmental quality and economic development are interrelated. According to **Abdouli and Hammami (2017**), there is evidence for both a one-way causal link between environmental quality and growth, on one hand, and a causative flow in the other direction, on the other hand, with growth driving environmental change. According to the research, increased economic activity—including production, distribution, and trade—degrades the quality of the environment because it causes biodiversity loss, deforestation for the creation of industries and manufacturing facilities, and carbon emissions from the use of heavy energy. Likewise, the findings of **Danish and Wang (2018), Saud et al. (2019), and Akadiri et al. (2019)**—which found a reciprocal connection between the quality of the environment and economic performance. This shows that while economic success is constrained by environmental quality, environmental vulnerability is increased by economic performance. This illustrates how tighter environmental controls designed to enhance environmental quality can restrict industrial/manufacturing activities, which consequently slows economic growth**(Olaniyi et al., 2023)**.

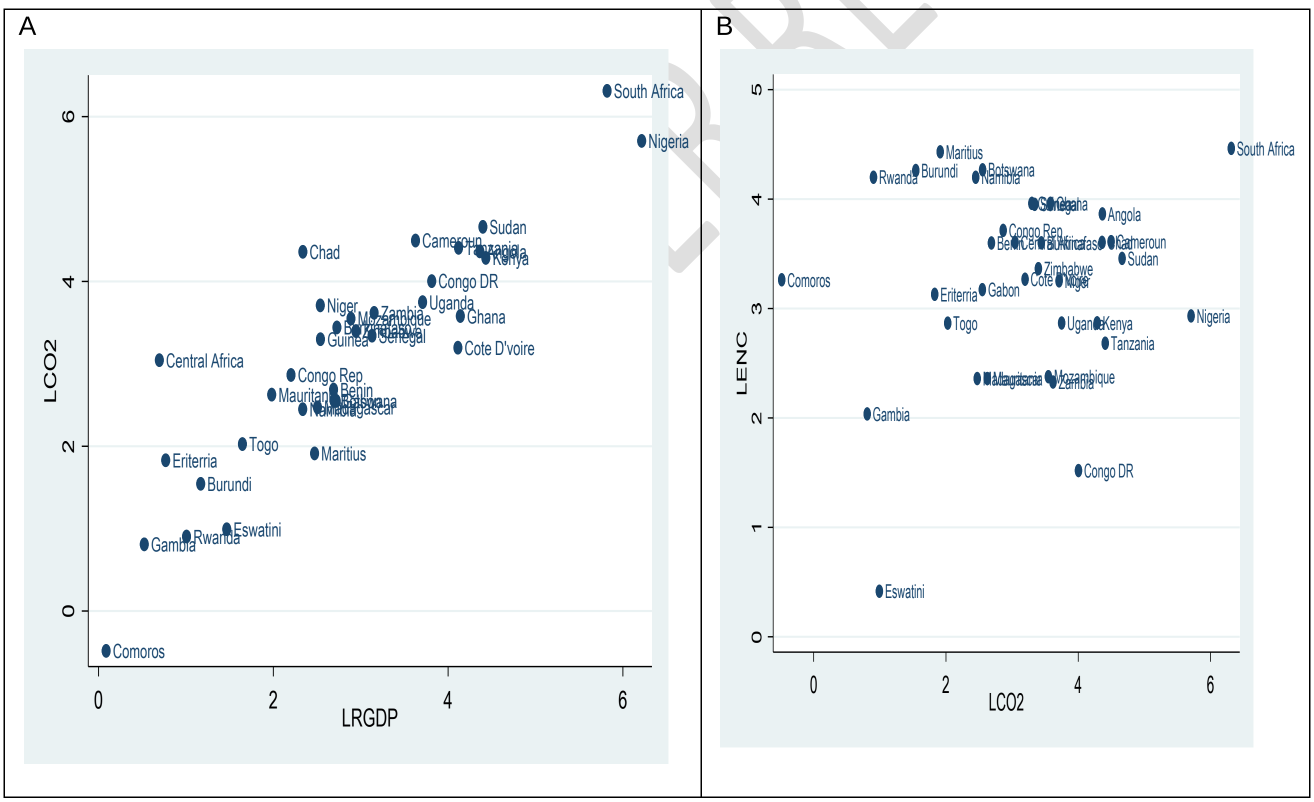
Meanwhile, SSA countries, which are solely grouped into middle-income and low-income economies, are currently experiencing influx of all sorts of imports due to globalization. For instance, products like auto tailpipes, used electrical and electronics equipment (UEEE) and used clothing, which cost tens of billions of dollars, which release harmful pollutants, are prevalent across the SSA countries **(Abubakar *et al.,* 2018; Agbo, 2018**). As latent demand for industrial technologies and consumer products like cars are stimulated across the developing economies, a significant amount of outdated, used, and on the verge of being discarded goods are making their way to low- and middle-income country marketplaces, especially in the SSA. As a result, there is a significant buildup of carbon emitting (energy-inefficient) technologies as well as secondhand goods in these countries without enough funds to deal with concerns like air pollution, climate change, or other environmental **problems(Olaoye & Dauda, 2022)**. The empirical results show that it may be difficult to predict how international trade has induced energy consumption with its attendant effects on the climate in SSA.Additionally, given that trade in manufactured goods is a part of ecosystems and some anti-globalization activists contend that increased global trade is fundamentally detrimental to the environment, it is possible to conclude that this practice is even more harmful **(Krugman et al., 2013).**It is clear that trade in manufactured goods has a considerable influence on the quality of the environment, especially in the developing nations. Consequently, this is the reason why the interaction between environmental quality and trade seem to attract our attention in this study. While considerable damage has been brought about by climate change, the harms that can be expected if we continue on our current course of "business as usual," are on the edge of being truly catastrophic. However, as **Giddens (2009)**emphasizes, the creation of excessive climate change is not solely the result of ignorance; in reality, there is widespread awareness that enormous carbon emissions are being generated.

Thus, it is crucial to explicitly look into how energy consumption and international trade interact to affect how well are African countries doing in terms of environmental quality (**Quadri et al., 2023**). This is due to the fact that African economies have resolved to increase energy consumption that enhances environmental quality despite an abundance of cheap sources of energy to speed up economic activities in these countries(**Adigwe et al., 2023**). In light of this, ourpaper's subsequent sections are as follows: the review of the literature is covered in part 2, and research methodology is covered in section 3. The themes of sections 4 and 5 are respectively, empirical analysis and discussion of results, conclusion, and policy recommendations.

1.2 Stylized facts on Sub-Saharan African Economies

The SSA countries are divided into two of the middle-income countries are the economies with per capita gross national income of more than US$995, in the years 2015–17 while the low-income economies are those with equal to or less than US$995, in the same period. The average values of real gross domestic product (RGDP) and carbon emission (CO_2) for SSA countries from 1996 to 2020 are depicted in panel A of Fig. 1. It is evident that countries with higher level of RGDP such as Nigeria and South Africa are associated with higher level of carbon emissions while in countries such as Rwanda, Eswatini and the Gambia with low level of RGDP are associated with lower level of carbon emission. However, in panel B, the average values of energy usage and carbon emissions are depicted. The pattern of the relation between these two variables appears not too discernible.

Figure 1. Average RGDP, Energy Use and Carbon Emissions in Sub-Saharan Africa (1996–2020).



Source: Author's Computation from World Development Indicators (2021)

2.0 Review of Literature

According **to Baz et al. (2020)**, in Pakistan, found that energy use is causally linked with environmental quality with indications of an unequal impact.**Mesagan & Olunkwa (2020)** showed that capital has a substantial direct impact on carbon emission and that capital also drives energy usage to enhance environmental quality. While **Adejumo (2019)** found that in Nigeria energy consumption produces carbon with its attendant effects on environmental quality, and the study supports the EKC preposition. **Salahuddin & Gow (2019)** focused on Qatar, found that environmental damage is caused by both energy use and GDP per person. Between 1972 and 2012, I, n Iraq**Akadiri et al. (2019)**revealed a unit-directional relationship between energy use and CO_2 emissions as well as between economic performance and energy use.**Kahia et al. (2019)** in his study of 12 MENA countries found that as the economy expands, environmental quality deteriorates. Also, it was found that FDI, renewable energy, and global trade all enhance environmental quality by reducing CO2 emissions.According to**Bekun et al. (2019)**gave support for the EKC U-shaped hypothesis regarding the relationship between growth and ecological footprint.

According to **Charfeddine et al. (2018**), found that energy use has a positive and considerable impact on economic production, respectively. Similar circumstances for BRI economies between 1980 and 2016 were explored by **Saud et al. (2018**). They used the DSUR technique of estimate, and the results showed that trade, FDI, and financial development promote environmental quality while energy use and economic performance decrease it. **Rahman and Kashem (2017)**discovered that energy use, export, and population density have an adverse influence on the environment. **Eregha & Mesagan (2017**) investigated the position of various energy-dependent economies in Africa. They demonstrated that economic output is positively and dramatically impacted by energy usage and oil prices**(Adebiyi et al., 2023**).

The studies conducted by **Ahmad & Du (2017), Abdouli & Hammami (2017), Padhan et al. (2019), Akadiri et al. (2019), and Akadiri et al. (2019)** all appear to be remarkably comparable to this one. These earlier studies focused on the direction of influence between environmental quality, energy consumption, and economic growth, but the current study extended the frontiers of knowledge through the use of the recent CS-ARDL estimator, introduced by **Chudik et al. (2016)**, and alsointerconnects energy consumption and trade in order to ascertain if emission reduction through energy consumption assisted by international trade has a significant impact on the corresponding quality of the environment in SSA countries. This is the primary original contribution of the study.

3.0 Theoretical Framework and Methodology

3.1 Theoretical Framework and Model Specification

The theory of the treadmill of production, which highlights the manner in which the relentless pursuit of growth in the economy causes economies all over the world to become "entrapped on a treadmill," in which their well-being cannot be enhanced by economic expansion but the consequences of this pursuit of growth creates vast, detrimental environmental damage, provides the framework to examine the relationship between energy use and environmental quality in this study. The theory focuses on how businesses, which control the production process, are the main agents driving the treadmill through energy consumption, and explores the precise driving force that maintains the system of the treadmill so tenaciously, while somehow underscoring the manner in which the state (via environmental regulations) and labor force in general keep supporting the treadmill's continual propagation**(**Schnaiberg, et al., 2002**)**. According to the theory, environmental damage results from human pursuit of economic prosperity. The theory's central tenet is that the increased contribution of the manufacturing activities to aggregate production that results from intensive energy utilization leads to economic growth. As more strain is being placed on the environment and carbon emissions are produced as a result of energy utilization, environmental degradation intensifies (**Mesagan & Olunkwa**, **2020**; **Padhan et al., 2019**; **Kahia et al., 2019**)**.**The claim that increasing energy use and economic development have negative consequences on environmental quality is thus theoretically accurate. When the economy of a country is more accessible to international trade, it will have access to more energy-efficient technology, which will help to improve the unfavorable environmental situation. The model summarizing the consequences of the use of energy and regulatory factors on the environment in SSA countries following the above theoretical expositions**Afolabi, (2023)**:

$$EQ = f(ENC, RGDP, REQ, GCI) \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 1$$

Where EQ, RGDP, REQ and GCI denote total environmental quality (proxiedby CO_2), real GDP (a proxy for economic growth), regulatory quality and gross capital investment, in that order. The determinants are all expressed in logarithms (rep by the prefix “ln”) except the REQ which is in percentile. Thus, elasticity is used to express how the independent variables affect the quality of the environment.

Equation (1) is represented explicitly as;

$$ln\,EQ = \beta_0 + \beta_1 ENC_{i,t} + \beta_2\, ln\, RGDP_{i,t} + \beta_3 REQ_{i,t} + \beta_4\, ln\, GCI_{i,t} + \varepsilon_{i,t} \quad - \quad - \quad 2$$

where i represents a cross-section of countries; t stands for the years 1996 to 2020; β_0 is the intercept;β_1-β_4 are each variable's elasticities; and ε is the noise(error).

In this paper, we investigate whether the degree of trade openness among African economies affects how much energy use from industrial and domestic activities and how clean the environment becomes. Equation (3), which provides a rich method of modeling the moderating impact that internationalization has on the link between energy use and the quality of the environment in SSA, thereby captures the conditional impacts. The conditional effect is represented by include product of the trade openness and energy use as one of the explanatory factors in the equation.

$$ln\,EQ = \beta_0 + \beta_1 ENC_{i,t} + \beta_2\, ln\, TOP_{i,t} + \beta_3\, ln\, ENC_{i,t}\_TOP_{i,t} + \beta_4\, ln\, RGDP_{i,t} + \beta_5 REQ_{i,t} + \beta_6\, ln\, GCI_{i,t} + +\varepsilon_{i,t} - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 3$$

where TOP denotes trade openness; ENC_TOP is the interactive term of energy consumption and trade openness; and all other factors stay the same as they were before. The total impact of energy consumption which includes the marginal influence of trade on the quality of environment is arrived at by taking partial derivatives of equation (3):

$$\frac{\partial EQ_{i,t}}{\partial ENC_{i,t}} = \beta_1 + \beta_3 TOP_{i,t} - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 4$$

The sign and magnitude of this equation should be considered while interpreting it. Considering the sign, if $\beta_1 > 0$ and $\beta_3 < 0$, energy consumption deteriorates environmental quality (ECF) only when foreign trade offers energy-inefficient technologies. However, if $\beta_1 < 0$ and $\beta_3 > 0$, it implies that using energy-efficient technologies via foreign trade would make energy consumptionenhance environmental quality (EQ). Meanwhile, if$\beta_1 > 0$ and $\beta_3 > 0$, then energy consumption and foreign trade complementarily promote environmental quality (EQ). Lastly, if $\beta_1 < 0$ and $\beta_3 < 0$, the nexus of energy consumption-environmental quality (EQ) has amplifying influence in diminishingenvironmental quality. Considering the magnitude, if $\frac{\partial EQ_{i,t}}{\partial ENC_{i,t}} > 0$, energy consumption together with trade opennessenhance environmental quality (EQ) but if $\frac{\partial EQ_{i,t}}{\partial ENC_{i,t}} < 0$, both energy use and trade openness reduce the quality of environment in the sampled SSA countries.

3.2 Estimation Technique

The unique CS-ARDL estimating technique created by **Chudik et al. (2016)** is the primary analytical method employed by this paper. Aspects of the Mean Group (MG) and Pool Mean Group (PMG) estimators can be incorporated into the CS-ARDL thanks to **Chudik and Pesaran's (2015)** dynamic common correlated effects (DCCE) approach while accounting for cross-sectional dependence. It takes into consideration heterogeneous slopes, allows for small numbers of samples, concurrently analyzes both long- and short-run models, handles the problem of cross-sectional dependence, and assumes that parameters are expressed by similar characteristics. Additionally, it can be applied if the panel data is uneven and the series contains structural breaks. These are the five explanations for why we selected this estimator over others. Using the panel ARDL/PMG estimator, the validity of the CS-ARDL estimates is evaluated.Equations (2) in the panel ARDL version are expressed as;

$$\Delta y_{it} = w_i + \delta_i(y_{i,t-1} - \theta_i^{'} x_{i,t-1}) + \sum_{j-1}^{p-1} \phi_{ij} \Delta y_{i,t-j} + \sum_{j-0}^{q-1} \alpha_{ij} \Delta x_{i,t-j} + \varepsilon_{it} \quad - \quad - \quad 5$$

where y_{it} is environmental quality for economy i at time t; α_{ij} represents a matrix of the regressors(factors); $\theta_i^{'}$ is a connection between y_{it} and x_{it}; in the long-run equilibrium, δ_i is the error correction term; ϕ_{ij} and α_{ij} show the connection between y_{it} and x_{it}in the short-run; and the items in the parentheses denotesin the long-run link.

Chudik et al. (2016)created the CS-ARDL model by adding cross-sectional averages to the dependent and explanatory variables, which accounts for gradient asymmetry and cross-sectional relationships. Equation (5) can be changed to be stated as its CS-ARDL equivalent, which is:

$$\Delta y_{it} = \mu_i + \delta_i(y_{i,t-1} - \theta_i^{'} x_{i,t-1} + \delta_i^{-1} n_i \overline{y_t} + \delta_i^{-1} \varphi_i^{'} \overline{x_t}) + \sum_{j-1}^{p-1} \phi_{ij} \Delta y_{i,t-j} + \sum_{j-0}^{q-1} \alpha_{ij} \Delta x_{i,t-j} + \sum_{j-0}^{p-1} \tau_{ik} \Delta \bar{y}_{t-j} + \sum_{j-0}^{q-1} \Delta_{ik} \varphi \bar{x}_{t-j} + \varepsilon_{it} \quad - \quad - \quad 6$$

Where $\overline{y_t}$ and $\overline{x_t}$are the cross-sectional averages of the cause-and-effectfactors, respectively.

We first carried out some basic testing before applying the CS-ARDL and PMG estimators. These include the panel unit root test, slope homogeneity test, cross-sectional dependence (CD) test, and panel cointegration test. In an attempt to avoid unclear and biased estimates in panel data analysis due to differences in spatio-temporal features, and spatial effects, a CD test must be performed (**Afolabi, 2023; Majeed et al., 2022**). The CD test, which **Pesaran (2004)**first introduced, is described as:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \rho ij\right) \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 7$$

where, T, N and ρ_{ij} stand respectively for time, panel data size, and correlation coefficient. The alternative hypothesis contradicts the null hypothesis of the CD test, which claims that there is CD in the sampled nations.

For the dissimilaritiesin the demographic and economic profile of these SSA countries, it is crucial to perform the test for slope homogeneity across the cross-sectional units after the CD test. The estimations can be incoherent if slope heterogeneity is not taken into consideration (**Afolabi, 2023**; **Zuo et al., 2022**). As a result, this study makes use of the slope homogeneity test that **Pesaran and Yamagata (2008**) presented. This is how its test statistic is expressed:

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}} (2K)^{-\frac{1}{2}} \left(\frac{1}{N} \tilde{S} - k\right) \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 8$$

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}} \left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}} \left(\frac{1}{N} \tilde{S} - k\right) \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 9$$

Where Δ˜SH and Δ˜ASH are delta tilde and adjusted delta tilde, respectively. The alternative hypothesis of the slope homogeneity test indicates that the gradients are not homogeneous in the cross-sections, contrary to the null hypothesis.

After the slope homogeneity and CD testing, we conducted the panel unit root test. Im, **Pesaran and Shin**(IPS) and Levin-Lin Chu are two examples of first-generation unit root approaches, but they are unable to resolve CD issues (**Afolabi, 2023)**. We thus made use of the second-generation cross-sectional augmented CADF and IPS (CIPS), by **Pesaran (2007)**, to establish the order of integration of each variable and account for the observed cross-sectional dependence among the sampled nations. The CIPS test statistic's formula is:

$$CIPS = \frac{1}{N}\sum_{i=1}^{n} \Delta CA_{i,t} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad 10$$

$$\Delta CA_{i,t} = \lambda_i + \lambda_i CA_{i,t-1} + \lambda_i \overline{CA_{t-1}} + \sum_{l=0}^{p} \lambda_{il} \Delta \overline{CA_{t-1}} + \sum_{l=0}^{p} \lambda_{il} \Delta CA_{i,t-1} + \mu_{it} \quad - \qquad 11$$

Where λ_i, $CA_{i,t-1}$, $\Delta CA_{i,t}$, $\overline{CA_{t-1}}$ and $\Delta\overline{CA_{t-1}}$ denotes the intercept, the cross-sectional units, its, first difference, its mean values, and the cross-sectional units' first difference, in that order.

The panel cointegration test is run following the panel unit root test to assess the status of the long-term linkages between the variables. In contrast to more well-known cointegration methods like **Kao and Pedroni**, the **Westerlund**test, developed by **Westerlund in 2007**, delivers objective results and takes CD and heterogeneity into account. The following is a list of expected test results for the **Westerlund** test:

$$\alpha_i(L)\Delta y_{it} = \delta_{1i} + \delta_{2i} t + \alpha_i (y_{it-} - \beta_i^{`} x_{it-1} + \lambda_i(L)^{v_{it}}) + e_{it} \quad - \quad - \quad - \quad - \qquad 12$$

Where $\delta_{1i} = \alpha_i(1)\varphi_{2i} - \alpha_i\varphi_{1i} + \alpha_i\varphi_{2i}$ and $\delta_{2i} = -\alpha_i\varphi_{2i}$ β_i is the EC coefficient and α_i isthe path in which the regressor and regressand cointegrate.

The flexibility of this technique partially justifies its use by permitting the addition of new variables or the analysis of different functional forms to better capture the intricacies of the relationship being studied. This guarantees that the analysis is customized to the particular features of the data and research issue under consideration. Overall, adoption of CS-ARDL Chudik et al. (2016) in this study provides a strong and appropriate methodological framework for examining how trade affects the relationship between energy usage and environmental quality in Sub-Saharan Africa, mitigating its effect.

3.3 Data Descriptions and Sources

The study cut-across 35 of 46 SSA countries due to data limitation. The selected 35 countries (see the appendix) are divided into two strata of low-income and middle-income economies. Low-income economies are those with per capita gross national incomes of $995 or less in the years 2015–17, while middle-income economies have per capita gross national incomes of over $995 (World Economic Outlook, 2019).We employed annual secondary data for the period of 1996-2020. Table 1 shows the description and the sources of variables.

Table 1: Data Descriptions and Sources

Variables	Definition	Description	Data Source
EQ	Environmental Quality	captured with carbon emissions (CO_2) measured in kilo tonnes: EQ decreases as CO_2 increases.	World development Indicator, 2022
RGDP	Real Gross Domestic Product	Captured with GDP (US$ Billion 2015 constant)	World development Indicator, 2022
ENC	Energy use	Captured with fossil fuel energy consumed per capita (EN)	World development Indicator, 2022
GCI	Gross Capital Investment	Proxied with gross capital formation	World development Indicator, 2022
TOP	Trade Openness	Captured with trade in % of GDP	World development Indicator, 2022

REQ	Regulatory Quality	Captured with quality of regulations (in Percentile Rank)	World Governance Indicator (2022)
ENC*TOP	Energy use interaction and trade openness interaction	Captured with multiplication energy consumption and trade openness	Derived

Source: Author's Compilation

4.0 Empirical Analysis and Discussion of Results

4.1 Preliminary Analysis

The full sample (the total of the two groups), middle-income countries (MICs), and low-income countries (LICs) are all represented by descriptive statistics in Table 2, as well as the important variables of interest. Although it averaged about 33.17% across the entire sample, it demonstrates that energy use is higher in MICs than in LICs, as expected. This directly correlates with economic activity as represented by RGDP, where the average, minimum, and maximum values of real GDP are higher in MICs than LICs despite having fewer observations. The relatively higher real GDP in MICs in conjunction with higher energy consumption leads to higher carbon emissions in the MICs than in LICs with 73,983 kt and 24,773 kt respectively. This is a pointer that LICs are likely to be faced with less environmental challenges associated with energy use than the MICs, all things being equal.Similarly, the Sub-Saharan African economiesare somewhat trade opened economies with about 63% but MICs seem to be more opened to international trade with 78% than LICs with 52%. In general, regulatory quality seems to be low in SSA but with higher average in the MICs than in LICs with 36.35% and 21.03% respectively.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ENC	875	33.1743	22.4628	0	88.1487
RGDP	875	3.37E+10	7.53E+10	5.42E+08	5.09E+11
GCI	875	21.761	9.276	1.525	79.401
CO2	875	45863.185	88678.343	290	560859.98
TOP	875	63.755	29.393	0.757	175.798
REQ	875	27.599	19.702	0.474	86.058
		Low-Income Countries			
ENC	500	28.388	19.205	0	70.9902
RGDP	500	1.31E+10	1.84E+10	5.42E+08	9.73E+10
GCI	500	20.688	9.729	1.525	60.156
CO2	500	24773.113	23681.859	290	106250
TOP	500	52.871	22.226	0.757	132.383
REQ	500	21.033	14.707	0.474	60.096
		Middle-Income Countries			
ENC	375	39.556	24.811	0	88.149
RGDP	375	6.12E+10	1.07E+11	2.24E+09	5.09E+11
GCI	375	23.192	8.436	11.825	79.401
CO2	375	73983.28	127441.15	2080	560859.98
TOP	375	78.266	31.47	16.352	175.798
REQ	375	36.354	22.001	4.808	86.058

4.2 Correlation Analysis

The magnitude and direction of the correlations between the regressand and the relevant regressors are checked using the correlation test. The intensity of the association raises the question of whether multicollinearity exists or not. Table 3 correlation test results show that there are relatively minor correlations between the factors taken into account, with real GDP having the strongest link with carbon emissions in LICs, MICs, and the total sample. The outcome reveals an absenceof multicollinearity in the model and that there is no particularly strong correlation between the variables. As a result, multicollinearity is not a concern when incorporating all the independent variables into the empirical model.

Table 3: Correlation Matrix

Variables	ENC	RGDP	GCI	CO2	TOP	REQ
Full Sample						
ENC	1					
RGDP	-0.018	1				
GCI	-0.003	0	1			
CO2	0.021	0.881	0.003	1		
TOP	0.015	-0.201	0.381	-0.186	1	
REQ	-0.05	0.107	0.102	0.15	0.203	1
Low-Income Countries						
ENC	1					
RGDP	-0.012	1				
GCI	0.005	0.293	1			
CO2	0.176	0.865	0.356	1		
TOP	0.064	-0.244	0.39	-0.123	1	
REQ	-0.053	-0.087	0.249	-0.11	0.025	1
Middle-Income Countries						
ENC	1					
RGDP	0.133	1				
GCI	0.048	-0.154	1			
CO2	0.313	0.871	-0.163	1		
TOP	0.13	-0.477	0.353	-0.439	1	
REQ	0.584	-0.008	-0.141	0.083	0.058	1

4.3 Cross-sectional Dependence

Following the variance in the homogeneousfeaturesof the sampled countries, cross-sectional dependence (CD) testing is essential in panel analyses. The **Pesaran** CD test result is displayed in Table 4, and it shows that the null hypothesis of no CD could not be accepted at the 1% level of significance. As a result, the dynamics of variables (including carbon emissions, energy usage, real GDP, trade openness, and capital creation) could affect other nations in the sample. This suggests that LICs and MICs in SSA are cross-sectionally reliant. Overall, the outcome supports the Sub-Saharan African region's interconnectedness.

Table 4: Cross-Sectional Dependence

Variable	Full Sample	Low-Income	Middle-Income
lnENC	6.18 (0.0000)	5.23 (0.0000)	4.64 (0.0000)
lnRGDP	102.09 (0.0000)	53.62 (0.0000)	46.89 (0.0000)

lnGCI	12.02 (0.0000)	14.37 (0.0000)	1.2 (0.229)
lnCO2	64.09 (0.0000)	41.92 (0.0000)	20.37 (0.0000)
lnTOP	8.81 (0.0000)	8.71 (0.0000)	9.32 (0.0000)
REQ	42.22 (0.0000)	16.78 (0.0000)	25.85 (0.0000)

4.4 Analysis of The Unit Root

Following the CD test, stationarity tests utilizing appropriate techniques must be carried out. The CIPS and CADF unit root techniques, that is capable of successfully manage CD concerns, were introduced by **Pesaran (2007**). Table 5 presents the results of these two methods and shows that the variables have heterogeneous order of integration throughout the three models. Some of the series become stable at (I(0)), whereas others do not until they have first been differenced (I(1)). This satisfies a prerequisite for using the CS-ARDL framework. This finding raises the prospect that the variables could cointegrate, necessitating the execution of a cointegration test to explore this potential.

Table 5: The Unit Root Tests

	Full Sample			
Variable	**CADF**		**CIPS**	
	Level	First Diff	Level	First Diff
lnENC	-2.309*	-3.018*	-2.738*	-4.766*
lnRGDP	-1.756	-1.994***	-2.021	-3.984*
lnGCI	-2.017***	-2.757*	-2.332*	-4.752*
lnCO2	-1.757	-2.466*	-2.623*	-4.939*
lnTOP	-1.159	-2.918*	-1.73	-4.668*
REQ	-1.732	-2.734*	-2.434*	-5.027*
	Low-Income Countries			
lnENC	-2.885*	-3.152*	-2.909*	-4.796*
lnRGDP	-1.865	-2.066***	-1.913	-4.127*
lnGCI	-2.158**	-2.791*	-2.657**	-4.893*
lnCO2	-1.875	-2.552*	-2.582*	-4.919*
lnTOP	-1.43	-2.997*	-1.804	-4.908*
REQ	-2.066***	-2.499*	-2.401*	-4.718*
	Middle-Income Countries			
lnENC	-2.17***	-2.613*	-2.144***	-4.816*
lnRGDP	-1.768	-1.844*	-2.323**	-3.616*
lnGCI	-1.734	-2.51*	-1.772	-4.975*
lnCO2	-1.808	-2.308*	-2.297**	-4.798*
lnTOP	-1.602	-2.876*	-1.948	-4.517*
REQ	-1.589	-2.966*	-2.637*	-5.42*

Note: *, **, & * are 1%, 5% & 10% level of sig. respectively**

4.5 Analysis of homogeneity slope

To prevent inconsistent panel estimators, slope parameter status must be determined prior to panel data estimation. Both the model with an interactive term of energy usage and trade openness (Model B) and the model without an interactive element (Model A) are subjected to the slope homogeneity test. According to Table 6, which presents the results of the slope homogeneity test established by **Pesaran and Yamagata (2008)**, the null hypothesis that the slope parameters are uniform throughout the three panels is rejected. The variability in slopes across the sampled nations is amply demonstrated by this result. Therefore, among other factors, Sub-Saharan African nations differ in their levels of energy use and environmental degradation (CO2).

Table 6: Testing for slope heterogeneity

	Full Sample			
	MODEL A		MODEL B	
	SH	ASH	SH	ASH
VALUE	27.598	31.657	20.029	24.288
PROB	0.000	0.000	0.000	0.000
	Low-Income Countries			
VALUE	19.118	21.93	14.253	17.284
PROB	0.000	0.000	0.000	0.000
	Middle-Income Countries			
VALUE	16.84	19.317	11.883	14.411
PROB	0.000	0.000	0.000	0.000

4.6 Analysis of Cointegration

Due to the shortcomings of conventional cointegration test methodologies, the **Westerlund (2007)** 2nd-generation test was employed. in an attempt to remedy the longitudinal dependency observed across SSA countries. Table 7 cointegration result shows cointegration in all three panels for both Models A and B. This merely suggests that since these variables co-move over time, there is cointegration between environmental degradation, energy use, real GDP, trade openness, and gross capital investments.

Table 7: Cointegration Test

	MODEL A			MODEL B		
	FULL SAMPLE					
Statistic	Value	Z-value	P-value	Value	Z-value	P-value
Gt	-2.237	-1.486	0.069	-2.305	0.701	0.758
Ga	-6.75	2.603	0.995	-6.136	5.476	1
Pt	-13.706	-3.269	0.001	-14.788	-1.854	0.032
Pa	-7.537	-1.151	0.125	-7.123	1.948	0.974
	LOW-INCOME COUNTRIES					
Gt	-2.46	-2.094	0.018	-2.462	-0.158	0.437
Ga	-6.87	1.892	0.971	-6.101	4.158	1
Pt	-7.576	-0.273	0.392	-8.791	0.599	0.726
Pa	-6.257	-0.087	0.465	-5.617	2.242	0.988
	MIDDLE INCOME COUNTRIES					

Gt	-1.94	0.148	0.559	-2.462	-0.158	0.437
Ga	-6.591	1.791	0.963	-6.101	4.158	1
Pt	-11.159	-3.866	0	-8.791	0.599	0.726
Pa	-8.405	-1.214	0.112	-5.617	2.242	0.988

4.7 Presentation and discussion of empirical results

In light of the findings from the preliminary tests, the CS-ARDL model is expected to shed more light on the connection between energy use and the quality of the environment in Sub-Saharan Africa (Model A) and assess the mitigating impact of trade openness in lessening the influence (Model B). The results of the analysis, which was conducted on three panels (the complete sample, low-income countries (LICs), and medium-income countries (MICs), are shown in Table 8. The long-run outcomes are provided following the short-run estimations, which are displayed in the top half of the Table.

According to Model A's findings, energy use, regardless of the temporal dimension, has a favorable influence on emissions of carbon in both LICS and MICs. The positive effect demonstrates that as energy consumption rises, environmental degradation occurs in both LICs and MICs, but it is only substantial in the case of MICs. This suggests that increased energy use for industrial purposes causes a rise in carbon emissions, which enables both short- and long-term damage of the environment. Additionally, both in the short- and long-term, Model A shows positive elasticities between carbon emission (CO2) and RGDP as well as GCI in the chosen African countries, which is empirical proof of growing industrial activity in these countries.Empirically, this result is consistent with those made by**Baz et al. (2020**), **Faruq (2019**), **Adejumo (2019)**, and **Salahuddin & Gow (2019)**, who found that energy usage promotes environmental degradation in Pakistan, Africa, Nigeria, and Qatar, respectively. The outcome emphasizes the trade-off between energy use and environmental quality in Sub-Saharan Africa's middle-income and low-income nations.

Table 8: Empirical Analysis

	MODEL A			**MODEL B**		
	Full Sample	**Low-Income**	**Middle Income**	**Full Sample**	**Low-Income**	**Middle Income**
D.lnCO2	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
ECT	-1.35(0.039)*	-1.345(0.06)*	-1.27(0.069)*	-1.418(0.047)*	-1.422(0.092)*	-1.355(0.069)*
	Short Run Est.			Short Run Est.		
lnCO2(-1)	-0.35(0.039)*	-0.345(0.06)*	-1.27(0.069)*	-0.418(0.047)*	-0.422(0.092)*	-0.355(0.069)*
LnRGDP	0.168'(0.104)	0.168(0.124)	0.204(0.132)	0.413(0.139)	-0.006(0.108)	0.296(0.101)*
LnENC	41.313(49.937)	37.524(59.68)	0.68(0.34) **	96.70(84.40)	302.1(220.3)	-5.809(2.262)**
LnGCI	0.007 (0.037)	0.03(0.028)	-0.05(0.046)	-0.045(0.053)	0.004(0.035)	-0.126(0.058)**
REQ	-0.003(0.002)	0.001(0.001)	0.004(0.003)	-0.003(0.001)	0.001(0.001)	-0.006(0.004)*
LnTOP				92.81(63.99)	194.7(145.8)	-5.539(1.953)*
lnENC_TOP				-29.07(20.84)	-53.66(44.35)	1.499(0.564)*
	Long Run Est.			**Long Run Est.**		

REQ	-0.002(0.001) ***	0.001(0.001)	-0.003(0.002)	-0.002(0.001)	0.001(0.001)	-0.004(0.003)
LnENC	31.504(38.116)	21.42(40.36)	0.52(0.252) **	67.01(62.09)	189.8(135.6)	-5.113(2.082)**
LnGCI	0.006(0.028)	0.018(0.02)	-0.031(0.038)	-0.039(0.039)	0.010(0.035)	-0.095(0.049)***
LnRGDP	0.127(0.081)	0.129(0.108)	0.131(0.103)	0.107(0.101)	-0.218(0.279)	0.221(0.070)*
LnTOP				65.38(46.84)	132.7(92.39)	-4.682(1.653)*
lnENC_TOP				-20.81(15.65)	-37.28(28.58)	1.307(0.514)**
		Diagnostics			**Diagnostics**	
Obs	805	460	345	805	460	345
Groups	35	20	15	35	20	15
RMSE	0.07	0.05	0.08	0.08	0.05	0.09
CD Statistic	2.8	0.42	-0.38	1.23	-0.412	0.79
P-value	0.0051	0.6759	0.7013	0.2196	0.6792	0.4309

Note: *p < 0.01, **p < 0.05, ***p < 0.10

The importation of more energy-efficient technology, however, has the ability to partially offset the harm that energy usage does to the environment, according to empirical studies (**Kahia et al. 2019)**. Consequently, energy consumption variable and the trade openness variable interacted, and the outcome (given in Model B) is addressed here. Precisely, in the LICS, the result shows that tradeopenness increases the rate of carbon emission which indirectly deteriorates the environment while in MICs, trade is found to reduce the rate of carbon emissions which thus promotes the quality of the environment.Examining its moderating role on the nexus between energy consumption and environmental quality, in MICs, trade is found to significantly dampen the influence of energy use on the degree of carbon emission which therefore facilitates environmental quality both in the short and long runs whereas, in the case of LICs, the reverse is the case. Trade openness worsens environmental degradation. This shows that utilizing global trade to import energy-efficient technologies, particularly in MICs, may be a viable method of raising environmental standards in Sub-Saharan African nations. The result corroborates the findings of **Thuy, & Nguyen, (2022), and Ike et. al, (2020)** in developing economies and G-7 countries, respectively that trade openness dampens the consequence of CO_2 emissions on the damage of the environment. This implies that in promoting environmental sustainability firms in industrial/manufacturing sector must be compelled to import largely environmental-friendly technologies in their production activities.

Furthermore, the results show that real GDP, a measure of economic expansion, has a considerable short- and long-term impact on degradation of the environment in SSA's LICs and MICs. This outcome is conceivable given that rising economic activity increases energy demand and greenhouse gas emissions, which reduces environmental quality. The persistent economic expansion that SSA nations experienced, especially in the first ten years of the twenty-first century, could be blamed for the pollution- and emission-producing effects of economic growth (World Bank, 2018). Additionally, it might be linked to the countries' expanding efforts to industrialize and diversify their economies, which have significantly boosted the magnitude of economic activities in all markets (**Afolabi and Ogunjimi, 2020**).Due to the growing number of economic activities that have a negative impact on the environment and the natural environment, the environment is frequently the victim of these economic activities. If not immediately handled, it might make Sub-Saharan Africa's environmental issues even worse. According to **Afolabi (2023), and Zuo et al. (2022),**this findingfollows theoretical predictions and the views of these researchers.

Likewise, there is a link between big capital expenditures and energy use that is both positive and significant, although it only applies to MICs in the short- and-longterms. This demonstrates how Sub-Saharan Africa's growing investment money promotes environmental deterioration. This study contradicts the findings of **Awosusi et al. (2022)**, who discovered that, in Uruguay and the MENA region, respectively, trade openness exacerbated damage to the environment. However, the finding shows that degradation of the environment in SSA, and especially in the MICs on the continent, is a trade-off for the pursuit of economic expansion that drives increasing capital investment. Regardless of the time dimension, it was discovered that environmental regulation quality was inversely connected to carbon emission primarily in whole sample and MICs.This shows that passing and putting into practice suitable environmental laws has a noticeableinfluence on reducing carbon emissions and enhancing environmental quality. It is obvious that everyone in sub-Saharan Africa needs to adopt and adhere by laws and regulations that are more environmentally friendly, including greening (**Hassan et al., 2020)**. Not to mention, the error correction terms imply that the pace of recovery from a shock to a long-run equilibrium across economies is somewhat slow.

5.0 Conclusion and Policy Implications

This study addresses the growing concern about the relationship between environmental quality and human activities, particularly in Sub-Saharan Africa, where the pursuit of economic growth comes with significant energy consumption and environmental challenges. Despite an expanding body of knowledge on this topic, the role of international trade in influencing this relationship, especially in Sub-Saharan Africa, has not been thoroughly explored. In light of the escalating trade volumes between Sub-Saharan African countries and developed economies, this research aims to elucidate the moderating effect of trade on the environmental impact of energy usage.

The study classifies Sub-Saharan African countries into Middle-Income Countries (MICs) and Low-Income Countries (LICs) based on per capita income levels. Utilizing reliable databases, annual data for relevant variables spanning 1996–2020 were collected. The analysis employs the CS-ARDL estimator, with robustness tests conducted using the PMG estimator.

The findings reveal that, irrespective of the timeframe considered, energy utilization has an adverse impact on carbon emissions in both LICs and MICs within Sub-Saharan Africa. This indicates that energy consumption negatively affects the ecosystem across the region, with MICs experiencing more significant repercussions. When exploring the moderating role of trade in the relationship between environmental quality and energy usage, it is observed that, in MICs, trade significantly mitigates the adverse effects of energy consumption on carbon emissions, thereby fostering environmental quality in both short and long-term perspectives. Conversely, in LICs, the opposite trend is observed, indicating that trade exacerbates the environmental consequences of energy usage in these countries.

The findings of the study have notable policy implications, leading to key recommendations for Sub-Saharan African (SSA) countries to address the environmental challenges associated with energy usage and economic growth:

i. Adopting legislation to slow down environmental deterioration necessitates a strategic strategy that takes into account the unique political and economic circumstances of each Sub-Saharan African nation (SSA). Policymakers may encounter opposition from businesses hesitant to embrace environmentally friendly practices because of possible short-term financial implications in MICs, where economic growth is more prominent (e.g., Nigeria). A phased strategy with rewards for compliance and gradual enforcement might work well in certain situations. Effective development and enforcement of environmental rules may require international help and capacity-building initiatives in low-income countries (LICs) due to budget constraints.
ii. Although different nations in SSA have different levels of regulatory capacity and enforcement skills, ensuring compliance to environmentally conscious laws can be difficult. Ensuring compliance requires a strong political will and funding for law enforcement, especially for manufacturing and agricultural enterprises. When it comes to monitoring and enforcing compliance, public-private partnerships can be extremely important. Companies that exhibit a commitment to environmental sustainability can receive incentives.

iii. Government agencies in charge of trade and environmental control must work together to implement age restrictions on imported used items. Politicians need to strike a balance between economic and environmental issues, accounting for the effects on sectors of the economy that depend on the importation of used products. Impact analyses and stakeholder meetings can assist in determining reasonable age restrictions for various import categories, with exceptions made where needed to reduce trade disruptions.

iv. It is necessary to get over obstacles including high upfront prices, technological constraints, and dependency on fossil fuels in order to promote the usage of renewable energy sources. Governments can encourage public-private partnerships, tax breaks, and subsidies to encourage investment in renewable energy infrastructure. Local capacity for implementing and overseeing renewable energy systems can also be improved through focused capacity-building projects and technology transfer programs.

v. Maintaining environmental interests while luring in foreign investment is a difficult balance that must be struck when regulating foreign-owned companies and multinational enterprises. To ensure that corporations are held responsible for their environmental impact, governments need to bolster their regulatory frameworks and enforcement mechanisms. Enhancing supervision and accountability through transparency and public participation in decision-making processes helps guarantee that foreign firms adhere to international norms and national environmental laws.

References

Abdouli, M., & Hammami, S. (2017). Investigating the causality links between environmental quality, foreign direct investment and economic growth in MENA countries. *International Business Review*, *26*(2), 264-278.

Abubakar M. Joseph O. Raji A., Atolagbe E., Joseph A. and Taiwo M. (2018). Imperialism and Loss of Identity in Second Hand Clothes: The Nigerian Okrika Experience. Journal of language, technology & entrepreneurship in Africa vol.9(1).

Adejumo, O. O., Adejumo, A. V., & Aladesanmi, T. A. (2020). Technology-driven growth and inclusive growth-implications for sustainable development in Africa. *Technology in Society*, *63*, 101373.Ahmad, N., & Du, L. (2017). Effects of energy production and CO2 emissions on economic growth in Iran: ARDL approach. *Energy*, *123*, 521-537.

Adeola, A. O., Akingboye, A. S., Ore, O. T., Oluwajana, O. A., Adewole, A. H., Olawade, D. B., & Ogunyele, A. C. (2022). Crude oil exploration in Africa: socio-economic implications, environmental impacts, and mitigation strategies. *Environment Systems and Decisions*, *42*(1), 26-50.

Afolabi, J. A. (2023). Natural resource rent and environmental quality nexus in Sub-Saharan Africa: Assessing the role of regulatory quality. *Resources Policy*, *82*, 103488.

Afolabi, J., Ogunjimi, J.A., 2020. Industrialization: a roadmap to inclusive growth in Nigeria. Economics Pol. Rev. J. 18 (1), 20–28.

Afolabi, J.A., 2022. Does illicit financial flows crowd out domestic investment? Evidence from sub-saharan african economic regions. Int. J. Finance Econ. https://doi.org/ 10.1002/ijfe.2740.
African Countries," Journal of Economic Impact, Science Impact Publishers, vol. 4(3), pages 188-195. https://doi.org/10.52223/jei4032205

Agbo, C. O. A. (2011). Recycle materials potential of imported used vehicles in Nigeria. *Nigerian Journal of Technology*, *30*(3), 118-128.

Ahmad, M., Jiang, P., Majeed, A., Umar, M., Khan, Z., & Muhammad, S. (2020). The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: an advanced panel data estimation. *Resources Policy*, *69*, 101817.

Ahmed, Z., Wang, Z., & Ali, S. (2019). Investigating the non-linear relationship between urbanization and CO 2 emissions: An empirical analysis. *Air Quality, Atmosphere & Health*, *12*, 945-953.

Akadiri, S., Alola, A. A., Akadiri, A. C., & Alola, U. V. (2019). Renewable energy consumption in EU-28 countries: policy toward pollution mitigation and economic sustainability. *Energy Policy*, *132*, 803-

810.
Aladejare, S., 2022. Natural resource rents, globalisation and environmental degradation: new insight from 5 richest african economies. Res. Square. https://doi. org/10.21203/rs.3.rs-1379935/v2.
Amiri, H., Samadian, F., Yahoo, M., & Jamali, S. J. (2019). Natural resource abundance, institutional quality and manufacturing development: Evidence from resource-rich countries. *Resources Policy*, *62*, 550-560.
Arshad, Z. (2020). Renewable and non-renewable energy, economic growth and natural resources impact on environmental quality: Empirical evidence from south and southeast asian countries with CS-ARDL modeling. *International Journal of Energy Economics and Policy*.
Awosusi, A. A., Xulu, N. G., Ahmadi, M., Rjoub, H., Altuntaş, M., Uhunamure, S. E., ... & Kirikkaleli, D. (2022). The sustainable environment in Uruguay: the roles of financial development, natural resources, and trade globalization. *Frontiers in Environmental Science*, *10*, 875577
Ayobamiji, A.A., Kalmaz, D.B., 2020. Reinvestigating the determinants of environmental degradation in Nigeria. Int. J. Econ. Pol. Emerg. Econ. 13 (1), 52–71. https://doi. org/10.1504/IJEPEE.2020.106680.
Baz, K., Xu, D., Ali, H., Ali, I., Khan, I., Khan, M. M., & Cheng, J. (2020). Asymmetric impact of energy consumption and economic growth on ecological footprint: using asymmetric and nonlinear approach. *Science of the total environment*, *718*, 137364.
Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of the total Environment*, *657*, 1023-1029.
Biedermann, Z., 2018. Africa's dependency curse: the case of Botswana. Available at: https://roape.net/2018/09/27/africas-dependency-curse-the-case-of-botswana/.
Chudik, A., Mohaddes, K., Pesaran, M.H., Raissi, M., 2016. Longrun effects in large heterogeneous panel data models with cross-sectionally correlated errors. In: Essays in Honor of Man Ullah, 36. Emerald Group Publishing Limited, Bingley, pp. p85–p135.
Chudik, A., Pesaran, M.H., 2015. Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. J. Econom. 188 (2), 393–420.
Danish, & Wang, Z. (2018). Dynamic relationship between tourism, economic growth, and environmental quality. *Journal of Sustainable Tourism*, *26*(11), 1928-1943.
Destek, M. A., & Sinha, A. (2020). Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries. *Journal of Cleaner Production*, *242*, 118537.
environment in Africa: Lessons for policy. Scientific African, 16 (e01207).
Eregha, P. B., & Mesagan, E. P. (2017). Energy consumption, oil price and macroeconomic performance in energy dependent African countries. *Прикладная эконометрика*, (2 (46)), 74-89.
Fagbemi, F., & Kotey, R. A. (2022). Interconnections between governance shortcomings and resource curse in a resource-dependent economy. *PSU Research Review*, (ahead-of-print).
Faruq Quadri (2023) The Mediating Role of Institutional Quality on the Nexus between Oil Price Fluctuations and Current Account Deficits in Nigeria: A nonlinear ARDL Approach. Journal of International Cooperation and Development Vol 6 No 3. DOI: https//doi.org/10.36941/jicd-2023-0020
Faruq Umar, Quadri, (2019) A Re-Examination of the Relationship Between Foreign Flows and Economic Growth in LLDCs: Dynamic Fixed Effects (DFE)," Asian Journal of Economics and Empirical Research, Asian Online Journal Publishing Group, vol. 6(2), pages 169-179.
from Niger Delta, Nigeria. Global Ecol. Conserv. 22 (e00961), 1–12. https://doi.org/10.1016/j.gecco.2020.e00961.
Giddens, A. (2009). *Politics of climate change*. Polity.
Hassan, S.T., Xia, E., Lee, C., 2020. Mitigation pathways impact of climate change and improving sustainable development: the roles of natural resources, income, and CO2 emission. Energy Environ. 1–26. https://doi.org/10.1177/0958305X20932550, 0(0.
He, Y., Li, X., Huang, P., Wang, J., 2022. Exploring the Road toward environmental quality: natural resources, renewable energy consumption, economic growth, and greenhouse gas emissions. Sustainability 14 (1579), 1–16. https://doi.org/10.3390/ su14031579.
https://doi.org/10.1016/j.sciaf.2022.e01207.
Huang, S. Z., Sadiq, M., & Chien, F. (2021). The impact of natural resource rent, financial development,

and urbanization on carbon emission. *Environmental Science and Pollution Research*, 1-13.

Hussain, M., Abbas, A., Manzoor, S., Bilal, & Chengang, Y. (2023). Linkage of natural resources, economic policies, urbanization, and the environmental Kuznets curve. *Environmental Science and Pollution Research*, *30*(1), 1451-1459.

Ike, G. N., Usman, O., Alola, A. A., & Sarkodie, S. A. (2020). Environmental quality effects of income, energy prices and trade: the role of renewable energy consumption in G-7 countries. *Science of The Total Environment*, *721*, 137813.

Izvorski, I., Coulibaly, S., & Doumbia, D. (2018). Reinvigorating growth in resource-rich sub-Saharan Africa.

Kahia, M., Ben Jebli, M., & Belloumi, M. (2019). Analysis of the impact of renewable energy consumption and economic growth on carbon dioxide emissions in 12 MENA countries. *Clean Technologies and Environmental Policy*, *21*, 871-885.

Krugman, P. (2013). Revenge of the optimum currency area. *NBER macroeconomics annual*, *27*(1), 439-448.

Lee, M., & Gueye, C. A. (2015). *Do Resource Windfalls Improve the Standard of Living in Sub-Saharan African Countries?: Evidence from a Panel of Countries*. International Monetary Fund.

Mabogunje, A. L. (1995). The environmental challenges in sub-Saharan Africa. *Environment: Science and Policy for Sustainable Development*, *37*(4), 4-10.

Maino, M. R., & Emrullahu, D. (2022). *Climate change in Sub-Saharan Africa fragile states: evidence from panel estimations*. International Monetary Fund.

Majeed, A., Ye, C., Chenyun, Y., Wei, X., Muniba, 2022. Roles of natural resources, globalization, and technological innovations in mitigation of environmental degradation in BRI economies. PLoS One 17 (6), 1–22. https://doi.org/10.1371/ journal.pone.0265755.

Mesagan, E. P., & Olunkwa, N. C. (2020, March). Energy consumption, capital investment and environmental degradation: the African experience. In *Forum Scientiae Oeconomia* (Vol. 8, No. 1, pp. 5-16).

Mesagan, E.P., Adewuyi, T.C., & Olaoye, O.O. (2022). Corporate finance, industrial performance and

Nathaniel, S., & Khan, S. A. R. (2020). The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries. *Journal of Cleaner Production*, *272*, 122709.

Nwani, C., Adams, S., 2021. Environmental cost of natural resource rents based on production and consumption inventories of carbon emissions: Assessing the role of institutional quality. Resour. Pol. 74 (102282), 1–12. https://doi.org/10.1016/j. resourpol.2021.102282.

Ogunjimi, J.A., Oladipupo, D.O., 2019. Dynamics of demographic structure and economic growth in Nigeria. Asian J. Economics Empirical Res. 6 (2), 186–196.

Oji, C. E., & Afolabi, J. A. (2022). Economic and peace effects of terrorism in the 21st century. *International Journal of Public Law and Policy*, *8*(2), 144-157.

Olaniyi, O.O., Olaoye O.O., & Okunleye, O.J. (2023). Effects of Information Governance (IG) on profitability in the Nigerian banking sector. Asian Journal of Economics, Business and Accounting. 2023;23(18):22–35. https://doi.org/10.9734/ajeba/2023/v23i181055

Olaoye, O.O., & Dauda, R.O.S. (2022). "Energy Use, Financial Development and Pollution in Selected

Onyena, A.P., Sam, K., 2020. A review of the threat of oil exploitation to mangrove ecosystem: insights

Padhan, H., Haouas, I., Sahoo, B., & Heshmati, A. (2019). What matters for environmental quality in the Next Eleven Countries: economic growth or income inequality?. *Environmental Science and Pollution Research*, *26*, 23129-23148.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. IZA Discussion Paper Series No. 1240.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of applied econometrics*, *22*(2), 265-312.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics*, *142*(1), 50-93.

Quadri, F. U., Olaniyi, O. O., & Olaoye, O. O. (2023). Interplay of Islam and Economic Growth:

Rahman, M. M., & Kashem, M. A. (2017). Carbon emissions, energy consumption and industrial growth in Bangladesh: Empirical evidence from ARDL cointegration and Granger causality analysis. *Energy policy*, *110*, 600-608.

Rjoub, H., Ifediora, C. U., Odugbesan, J. A., Iloka, B. C., Xavier Rita, J., Dantas, R. M., ... & Martins, J. M. (2021). Implications of governance, natural resources, and security threats on economic development: Evidence from Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, *18*(12), 6236.

Salahuddin, M., & Gow, J. (2019). Effects of energy consumption and economic growth on environmental quality: evidence from Qatar. *Environmental science and pollution research*, *26*, 18124-18142.

Saqib, N., Duran, I.A., Hashmi, N., 2022. Impact of financial deepening, energy consumption and total natural resource rent on CO2 emission in the GCC countries: evidence from advanced panel data simulation. Int. J. Energy Econ. Pol. 12 (2), 400–409. https://doi.org/10.32479/ijeep.12907. Schnaiberg, A., 1970. Measuring modernism: theoretical and empirical explorations. Am. J. Sociol. 76 (3), 399–425.

Saud, B., & Paudel, G. (2018). The threat of ambient air pollution in Kathmandu, Nepal. *Journal of environmental and public health*, *2018*.

Schnaiberg, A., Pellow, D. N., & Weinberg, A. (2002). The treadmill of production and the environmental state. *The environmental state under pressure*, *10*, 15-32.https://doi.org/10.9734/ajeba/2023/v23i211127

Shen, Y., Su, Z.W., Malik, M.Y., Umar, M., Khan, Z., Khan, M., 2021. Does green investment, financial development and natural resources rent limit carbon emissions? A provincial panel analysis of China. Sci. Total Environ. 755 (142538), 1–58. https://doi.org/10.1016/j.scitotenv.2020.142538.

Sinha, A., Sengupta, T., 2019. Impact of natural resource rents on human development: what is the role of globalization in Asia Pacific countries? Resour. Pol. 63 (101413), 1–19. https://doi.org/10.1016/j.resourpol.2019.101413.

Thuy, D. P. T., & Nguyen, H. T. (2022). Effects of trade openness on environmental quality: Evidence from developing countries.

Tiba, S., & Frikha, M. (2019). The controversy of the resource curse and the environment in the SDGs background: The African context. *Resources Policy*, *62*, 437-452.
Unveiling the Long-run Dynamics in Muslim and Non-Muslim Countries. Asian Journal of Education and Social Studies, 49(4), 483–498. https://doi.org/10.9734/ajess/2023/v49i41226

World development indicators databank. Available at. https://databank.worldbank.org/source/world-development-indicators.

World Governance Indicators, 2021. World governance indicators databank. Available at: https://databank.worldbank.org/source/worldwide-governance-indicators.

Xiaoman, W., Majeed, A., Vasbieva, D. G., Yameogo, C. E. W., & Hussain, N. (2021). Natural resources abundance, economic globalization, and carbon emissions: Advancing sustainable development agenda. *Sustainable development*, *29*(5), 1037-1048.

Yameogo, C.E.W., Omojolaibi, J.A., Dauda, R.O.S., 2021. Economic globalisation, institutions and environmental quality in Sub-Saharan Africa. Res. Global. 3 (100035), 1–9.

Zuo, S., Zhu, M., Xu, Z., Oláh, J., & Lakner, Z. (2022). The dynamic impact of natural resource rents, financial development, and technological innovations on environmental quality: empirical evidence from BRI economies. *International Journal of Environmental Research and Public Health*, *19*(1), 130.

Appendix

country	ENC	RGDP	GCI	CO2	TOP	REQ	Country	ENC	RGDP	GCI	CO2	TOP	REQ
			Angola							Kenya			
Mean	37.05161	5.87E+10	28.03005	70892.53	99.7684	13.68423	Mean	16.99163	5.40E+10	19.02934	51925.73	48.89126	38.40462
Std dev	9.926249	2.32E+10	5.224198	10164.92	30.15368	4.94591	Std dev	1.459453	1.68E+10	2.618716	15458.57	9.6973	12.14446

	22.12	2.54E	17.71		51.88	7.065		12.99	3.43E	15.00		27.23	7.065
Min	487	+10	226	54670	745	217	Min	901	+10	382	33030	39	217
	48.30	8.72E	42.82		152.5	22.59		19.41	8.43E	24.95		64.47	48.80
Max	559	+10	085	87360	471	615	Max	169	+10	072	81010	887	383
Benin							Madagascar						
Mea	32.47	9.00E	17.97	9883.	51.67	31.94		10.59	9.59E	18.85	27468	53.78	28.94
n	975	+09	916	733	812	609	Mean	264	+09	782	.93	865	896
Std	7.859	2.81E	3.953	2962.	8.105	10.74	Std	0.013	1.99E	7.491	1643.	11.46	11.65
dev	682	+09	15	208	848	164	dev	223	+09	732	617	104	001
	13.33	5.07E	12.08		39.09	7.065		10.55	6.52E	9.526		34.03	7.065
Min	205	+09	604	5830	593	217	Min	672	+09	116	23040	06	217
	41.55	1.47E	26.38		65.26	48.36		10.62	1.32E	38.74		74.35	48.03
Max	419	+10	651	15090	827	956	Max	766	+10	61	29580	735	922
Botswana							Mauritius						
Mea	66.65	1.14E	29.01	13827	96.16	64.30		78.47	9.36E	22.83	5291.	114.5	64.73
n	946	+10	868	.87	458	351	Mean	927	+09	584	333	829	59
Std	3.702	2.78E	5.079	3734.	11.98	21.43	Std	6.272	2.60E	3.490	1193.	12.18	23.44
dev	099	+09	967	074	678	775	dev	691	+09	136	792	016	397
	60.17	6.98E	21.69		77.82	7.065		63.78	5.41E	17.27		85.88	7.065
Min	227	+09	278	8790	069	217	Min	766	+09	291	2960	374	217
	74.68	1.62E	39.11		125.7	77.17		84.54	1.39E	29.38		132.1	86.05
Max	798	+10	812	25810	83	391	Max	236	+10	878	6850	991	769
Burkina Faso							Mauritania						
Mea	36.59	8.76E	19.95		45.60	38.16		10.59	4.90E	30.14	10792	79.19	27.88
n	092	+09	875	22578	651	142	Mean	156	+09	703	.4	198	764
Std	0.003	3.51E	3.789	5974.	12.29	12.34	Std	0.000	1.33E	14.28	1964.	17.29	13.16
dev	897	+09	381	004	53	331	dev	103	+09	799	209	093	726
	36.58	4.09E	13.45		30.36	7.065		10.59	3.33E	9.543		49.01	7.065
Min	346	+09	168	13840	824	217	Min	143	+09	8	7610	694	217
	36.60	1.53E	27.39		64.03	50.27		10.59	7.32E	49.16		110.7	
Max	339	+10	178	32210	585	027	Max	19	+09	682	14290	881	60
Burundi							Mozambique						
Mea	70.90	2.55E	11.44	2861.	31.46	13.34		8.027	1.06E	34.42	26984	75.90	28.51
n	534	+09	916	333	396	998	Mean	336	+10	761	.67	096	752
Std	0.034	5.05E	4.890	1044.	9.072	5.871	Std	2.096	4.87E	13.02	5039.	25.59	9.926
dev	857	+08	496	094	461	138	dev	362	+09	6	496	221	838
	70.80	1.90E	2.781		20.96	4.891		5.321	3.77E	18.32		37.74	7.065
Min	327	+09	138	1800	405	304	Min	251	+09	691	19160	057	217
	70.99	3.23E	18.97			26.44		12.61	1.82E	60.05		127.2	47.82
Max	019	+09	487	4870	47.2	231	Max	995	+10	831	36120	042	609
Cameroun							Namibia						
Mea	26.20	2.49E	18.54	84401	45.59	18.62		65.03	8.24E	21.91	11693	94.31	52.00
n	853	+10	679	.87	944	713	Mean	695	+09	757	.33	69	154
Std	9.618	7.36E	0.771	3182.	5.476	4.896	Std	1.930	2.33E	5.121	2331.	11.85	17.26
dev	091	+09	232	404	809	571	dev	238	+09	193	085	499	008
	14.65	1.45E	17.19		33.73	7.065		61.75	4.87E	13.69		75.13	7.065
Min	179	+10	233	79220	898	217	Min	233	+09	207	9200	927	217
	38.31	3.76E	19.81		56.92	25.35		67.11	1.13E	34.77		123.7	68.64
Max	786	+10	805	90120	442	885	Max	417	+10	655	19190	628	865
Central African Republic							Niger						
Mea	36.76	1.88E	14.43	21747	42.66	10.44		27.86	7.25E	22.53	27741	39.06	25.17
n	89	+09	865	.87	578	018	Mean	699	+09	806	.87	491	82
Std	0.018	2.69E	6.722	1501.	8.304	4.523	Std	18.05	2.68E	7.764	8331.	6.056	8.259
dev	716	+08	864	435	923	707	dev	342	+09	145	529	909	258
	36.71	1.50E	6.404		31.49	5.288		13.71	4.11E	11.19		30.83	7.065
Min	083	+09	793	18690	425	462	Min	825	+09	953	16300	439	217
	36.81	2.55E			57.14	21.19		66.63	1.26E	32.64		51.94	40.19
Max	032	+09	26	24760	355	565	Max	141	+10	046	42720	599	608
Chad							Nigeria						
Mea	36.76	7.12E	27.27	50691	74.30	12.39		18.93	3.37E	24.76	25830	37.28	17.84
n	795	+09	253	.6	544	743	Mean	216	+11	299	4.8	27	192
Std	0.000	2.97E	10.61	17152	18.14	3.075	Std	1.273	1.29E	8.338	26024	9.785	6.145
dev	163	+09	599	.99	185	01	dev	984	+11	632	.09	754	608

Min	36.76 775	2.82E +09	13.69 15	28700	46.61 003	7.065 217	Min	15.85 414	1.61E +11	14.90 391	22273 0	16.35 219	7.065 217
Max	36.76 851	1.10E +10	60.15 617	81650	126.3 508	20.39 801	Max	21.65 634	5.09E +11	40.61 495	30818 0	53.27 796	27.01 422
			Comoros							Rwanda			
Mea n	26.11 684	8.07E +08	16.54 146	414.6 667	37.34 154	9.427 354	Mean	66.63 572	5.74E +09	18.65 191	3719. 333	38.73 505	33.81 765
Std dev	0.012 841	1.75E +08	2.169 261	109.5 952	2.544 609	3.549 874	Std dev	0.000 535	2.91E +09	4.892 123	1103. 92	9.521 416	19.80 418
Min	26.07 828	5.42E +08	11.80 176	290	33.15 618	4.368 932	Min	66.63 412	1.95E +09	11.98 212	1960	27.35 119	7.065 217
Max	26.15 213	1.09E +09	19.24 888	640	42.99 615	17.83 784	Max	66.63 694	1.12E +10	26.13 304	5340	57.93 633	60.09 615
			Congo DR							Senegal			
Mea n	3.494 345	2.69E +10	15.64 844	46180 .8	59.33 81	5.794 3	Mean	50.80 452	1.44E +10	24.25 032	21233 .2	55.10 199	40.34 576
Std dev	1.186 73	9.83E +09	7.875 462	7064. 297	18.56 655	2.283 356	Std dev	3.160 653	4.24E +09	4.614 496	4525. 731	5.287 239	12.65 898
Min	1.639 733	1.62E +10	2.1	34010	25.04 194	1.630 435	Min	44.52 372	8.67E +09	15.84 806	15030	46.27 243	7.065 217
Max	5.815 208	4.53E +10	28.78 135	55500	90.74 761	9.803 922	Max	55.16 466	2.29E +10	35.14 423	29230	64.24 975	51.18 483
			Congo Rep							South Africa			
Mea n	33.57 808	8.73E +09	37.04 647	13834 .67	125.6 656	9.540 579	Mean	86.41 569	2.89E +11	17.05 086	48431 4.3	51.58 037	57.94 666
Std dev	8.618 692	2.06E +09	16.85 924	2681. 849	15.50 051	2.971 117	Std dev	1.111 266	5.55E +10	1.897 364	69018 .96	6.112 856	19.71 648
Min	15.82 491	5.93E +09	15.59 811	9190	93.00 286	4.807 693	Min	84.24 343	2.01E +11	12.40 005	36461 0	42.19 925	7.065 217
Max	42.04 299	1.23E +10	79.40 108	19200	156.8 618	16.91 542	Max	88.14 867	3.60E +11	21.28 725	56086 0	65.97 452	72.54 902
			Cote D'Ivoire							Sudan			
Mea n	28.00 792	3.69E +10	17.69 268	22803 .73	56.24 961	26.08 625	Mean	25.98 762	7.85E +10	27.20 592	90074 .8	21.81 321	7.217 962
Std dev	5.275 617	1.09E +10	3.684 289	2087. 699	7.264 271	11.16 777	Std dev	7.122 911	1.43E +10	6.981 29	13401 .11	14.58 275	2.022 818
Min	20.86 776	2.64E +10	12.02 348	18880	42.20 452	7.065 217	Min	12.97 351	4.57E +10	12.47 306	63870	0.756 876	3.846 154
Max	40.89 198	6.10E +10	23.48 476	26040	70.30 109	44.23 077	Max	32.82 946	9.73E +10	39.54 908	10625 0	44.34 437	10.86 957
			Eriteria							Tanzania			
Mea n	25.43 639	2.08E +09	18.85 808	5605. 333	57.14 438	4.381 538	Mean	10.73 134	3.39E +10	29.06 263	64036 .53	38.57 584	30.50 38
Std dev	4.008 241	1.09E +08	9.755 747	384.3 61	25.94 699	4.605 558	Std dev	3.411 028	1.48E +10	8.482 632	14021 .28	9.798 519	9.250 304
Min	19.10 594	1.79E +09	9.263 796	4840	27.97 214	0.473 934	Min	5.541 691	1.57E +10	14.89 974	43540	23.98 087	7.065 217
Max	35.21 807	2.25E +09	45.51 418	6330	116.6 175	14.67 391	Max	14.90 684	6.15E +10	41.01 825	84000	56.16 612	39.81 042
			Eswatini							Togo			
Mea n	8.188 844	3.32E +09	15.98 258	2401. 2	116.5 54	36.29 536	Mean	16.43 069	3.30E +09	20.16 297	5787. 867	79.79 031	20.58 925
Std dev	10.30 958	7.26E +08	3.520 765	165.4 368	31.69 747	11.90 161	Std dev	2.928 339	9.30E +08	5.011 852	1349. 281	16.10 392	6.416 777
Min	0	2.24E +09	11.82 455	2080	79.66 687	7.065 217	Min	12.01 933	2.19E +09	13.33 986	3460	54.37 207	7.065 217
Max	22.86 097	4.40E +09	23.69 217	2790	175.7 98	47.56 757	Max	24.10 152	5.19E +09	32.22 33	7890	112.7 61	36.95 652
			Gabon							Uganda			
Mea n	25.39 377	1.18E +10	25.79 133	13489 .47	85.04 596	33.63 249	Mean	17.59 937	2.30E +10	22.83 14	29605 .47	38.56 514	41.46 59
Std dev	6.142 287	2.06E +09	4.741 246	821.7 522	9.248 608	16.50 586	Std dev	0.035 599	9.94E +09	3.288 231	9369. 727	5.656 674	13.37 673

Min	16.46213	9.69E+09	19.25823	11990	70.06	7.065217	Min	17.54744	9.95E+09	16.44715	16910	30.04392	7.065217
Max	36.77855	1.55E+10	39.55766	15350	101.7019	63.58696	Max	17.76213	4.08E+10	30.81946	43290	56.25827	55.97826
Gambia							Zambia						
Mean	21.12148	1.20E+09	14.26366	2173.467	50.56259	29.49379	Mean	9.579782	1.48E+10	24.23123	31121.07	67.63584	28.27843
Std dev	22.31122	2.53E+08	7.081196	460.0216	7.035044	9.616254	Std dev	1.263403	6.13E+09	10.9553	4463.019	8.081647	8.569493
Min	0	7.88E+08	4.562497	1530	39.0891	7.065217	Min	6.736325	7.17E+09	14.65223	24720	56.12138	7.065217
Max	52.54034	1.69E+09	31.95424	3460	68.85879	44.54976	Max	12.02352	2.41E+10	42.80487	37570	80.45602	38.58696
Ghana							Zimbabwe						
Mean	42.01207	3.53E+10	21.69475	24214.13	79.54771	43.58583	Mean	31.12301	1.76E+10	11.07224	29163.47	70.53121	5.292439
Std dev	11.2125	1.53E+10	4.669964	7338.194	17.3153	14.44968	Std dev	5.357309	3.43E+09	5.298181	2276.076	14.75109	5.591081
Min	19.32334	1.70E+10	12.80999	14330	38.51686	7.065217	Min	23.67196	1.04E+10	1.525177	24600	50.02971	0.980392
Max	52.616	6.28E+10	29.00214	37650	116.0484	54.9763	Max	42.0693	2.20E+10	20.75046	33770	109.5216	23.36957
Guinea													
Mean	52.4918	7.33E+09	22.38813	17950.13	71.36174	15.85428							
Std dev	0.004461	2.39E+09	6.974725	5983.056	21.92024	4.362981							
Min	52.47736	4.46E+09	14.53812	9700	42.41507	7.065217							
Max	52.50051	1.27E+10	52.66984	28330	132.3825	22.28261							