Financial Access, Energy Demand, and Environmental Quality in Sub-Saharan African Economies

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Abstract

Financial access has a positive correlation with energy demand. The type of energy, whether clean energy or fossil fuel, enabling financial access will contribute to environmental quality. This study investigates the complex relationship between financial access, energy demand, and environmental quality across 38 Sub-Saharan African (SSA) countries from 2000 to 2021. Using the cross-sectional autoregressive distributed lag (CS-ARDL) model and the Westerlund cointegration test, the analysis identifies significant long-run and short-run dynamics among the variables. The findings reveal that energy demand increases carbon emissions, indicating environmental degradation, while financial access plays a moderating role by reducing emissions. Additionally, the interaction between energy demand and financial access shows that financial inclusion reduces the adverse environmental impact of energy use. Real GDP and gross capital investment are found to exacerbate emissions, underscoring the environmental cost of economic expansion. The study therefore recommends for region-specific environmental policies that integrate financial development strategies with sustainable energy use to mitigate adverse ecological outcomes in SSA.

Keywords: Financial Access, Energy Demand, Environmental Quality, Sub-Saharan Africa, Cointegration

JEL Codes: Q56, Q43, O13, G21, C33

1.0 Introduction

Sub-Saharan Africa (SSA) faces a complex set of interrelated challenges involving rising energy demand, financial exclusion, and environmental degradation. The region's limited energy infrastructure coupled with significant percentage of the population without access to formal financial services hinder inclusive growth and sustainable development. These interconnected issues are especially relevant in the context of Sustainable Development Goal (SDG) 1, which focuses on eradicating poverty, and SDG 7, which emphasizes access to affordable and clean energy.

One of the key drivers of environmental degradation in SSA is the region's dependence on traditional and non-renewable energy sources. These sources not only generate high levels of carbon emissions but also negatively affect biodiversity and natural ecosystems. Asafu-Adjaye

(2003) notes that CO_2 emissions in developing economies are closely tied to economic activities such as industrialization, housing, and food production. Rapid population growth exacerbates these emissions through deforestation and loss of biodiversity. Similarly, Mesagan and Olunkwa (2020) observe that economic expansion, reflected by increases in Real GDP, often results in greater environmental harm due to the dominance of fossil fuels and coal as energy sources.

Despite experiencing significant economic growth in the early 2000s due to improved macroeconomic policies and political stability, many SSA countries still face deep-rooted structural issues. These include high income inequality, widespread poverty, outdated infrastructure, and weak environmental regulations (World Bank, 2018). The abundance of natural resources in the region such as crude oil, coal, uranium, and arable land offers immense opportunities for development but also raises concerns about overexploitation and environmental sustainability.

Financial inclusion presents conflicting outcomes. On one hand, access to formal financial services enables individuals and businesses to invest in cleaner technologies and energy-efficient solutions. On the other hand, digital financial inclusion, while accelerating economic growth, also contributes to increased energy consumption particularly when powered by non-renewable sources like diesel and coal. This paradox highlights the need to shed light on how financial inclusion interacts with energy consumption and the impact on environmental quality.

In 2021, only 43% of adults in SSA had access to formal financial services, reflecting a high level of financial exclusion (World Bank, 2021). Studies (Demirgüç-Kunt et al. 2018 have linked this exclusion to energy poverty and inequality in the region. Park and Mercado (2015) emphasize that finance is crucial for economic development, as it helps allocate resources toward productive and sustainable projects. However, there remains a gap in understanding how this financial participation influences environmental sustainability, especially in energy-intensive sectors. Moreover, the proliferation of mobile banking and digital financial services, while expanding access, has also raised environmental concerns. Digital finance servers, data centers, and networks require substantial energy infrastructure. If not powered by renewable sources, this trend could worsen the region's carbon footprint.

The environmental degradation across SSA, despite its renewable energy potential, has attracted the attention of policymakers and development partners. The growing global demand for natural resources, projected to triple by 2050, intensifies the need for sustainable resource management

(African Development Bank, 2014). As SSA countries embrace the need to transit from resource-dependent economies to more diversified and sustainable ones, understanding the role of financial inclusion and energy consumption in shaping environmental outcomes cannot be overemphasized

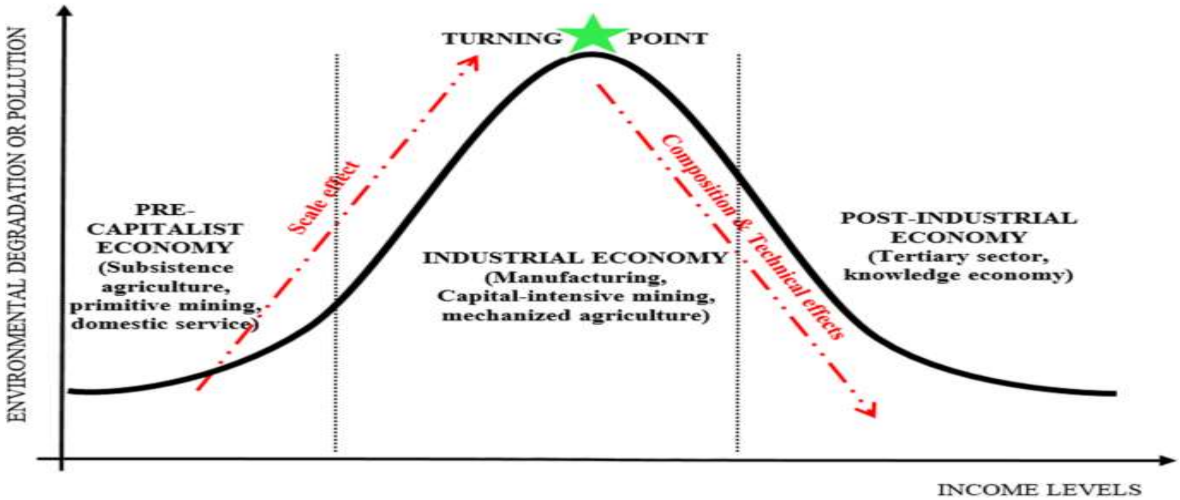
Therefore, this study aims to investigate the moderating impact of financial access on the relationship between energy demand and environmental quality in selected Sub-Saharan African economies. It also seeks to assess how financial access influences the interaction between energy demand and environmental quality within the context of Sub-Saharan African economies.

2.0 Literature Review

2.1 Theoretical Review

The Environmental Kuznets Curve provides a theoretical foundation for the relationship between economic growth and the environment (Cole 2004; Grossman and Krueger 1991; Soytas et al., 2007; Ang 2007). Kuznets in 1955 hypothesized that as economic development progresses, economic inequality will initially rise and then start to decline after attaining a turning point. The concept of the EKC is based on the effects of the switch in production from rural agriculture to urban industry. When industrial activity intensifies, pollution increases. As income levels rise, the industrial-heavy industry is gradually replaced by a production that is more cutting-edge and customer-focused. It is anticipated that this adjustment will offset the rise in pollution and eventually cause it to decline. Thus, environmental deterioration and pollution rise in the early phases of economic expansion, but the pattern changes at a particular level of wealth per capita (which will vary for different indicators), implying that environmental quality would increase during times of rapid economic growth (Stern, 2004).

Figure 1: Environmental Kuznets Curves



The Treadmill theory of production provides the theoretical foundation for other sociological traditions that address environmental risk and the persistence of contemporary unsustainable economic practices (Gould 2015), It explains how changes in the economy and environment interact which causes enormous environmental damage, It also, demonstrates how industrialized economies achieve sustained economic expansion accompanied with marginal increase in their well-being (Gould et al. 2004). As Schnaiberg (1980) opined in his original formulation of the "treadmill" metaphor, corporations, the state, and labour are all committed to economic progress. This "growth ideology" dominated both capitalist and socialist societies in the 20th century. Accordingly, the general consensus is that economic development provides the path to social progress and economic prosperity in the long-run (Gould et al., 2004). Through the expansion of production and rising capital intensity, according to Afolabi (2023), the pursuit of economic growth has inexorably increased environmental problems. The treadmill hypothesis, provides an explanation of the social costs of expanded production and the social processes involved in the generation and distribution of social surplus (Gould et al. 2008).

2.2 Empirical Review

Several scholars have investigated the complex relationship between financial inclusion and environmental sustainability, yielding mixed findings. Damrah, Satrovic, and Shawtari (2022) highlighted that information and communication technology (ICT) use enhances financial inclusion, environmental protection, and reduces CO_2 emissions. Similarly, Usman, Makhdum, and Kousar (2020) observed that financial inclusion has positive environmental effects in the world's 15 highest CO_2-emitting countries. In China, Liu, Hong, and Sohail (2021) found that most financial inclusion variables were linked to environmental degradation, while Shahbaz et al. (2022) reported that increased financial inclusion led to reduced emissions from 2011 to 2017. Feng et al. (2022) argue that high financial inclusion improves renewable energy use and reduces emissions, and Yang, Yaru, and Wang (2022) also observed a negative regional correlation in China.

Conversely, some scholars highlight financial inclusion's detrimental environmental effects. Ahmad and Satrovic (2023) attributed environmental degradation in ASEAN countries to financial inclusion alongside energy consumption and urbanization. Le et al. (2020) and Musah (2022) similarly reported that greater financial inclusion raises CO_2 emissions in Asian economies. Rehman et al. (2022) argued that lack of financial inclusion harms the environment in middle-income countries, but benefits high-income ones. Renzhi and Baek (2020) proposed an inverted U-shaped relationship—initially negative, then positive—between financial inclusion and environmental harm. In contrast, Fareed et al. (2022) suggested that innovation can counterbalance financial inclusion's negative environmental effects in the Euro Area. Nonetheless, some research found no significant relationship between financial inclusion and environmental sustainability (Saidi & Hammami, 2015; Eslami et al., 2021; Acheampong, 2019).

The literature on energy consumption and environmental quality offers extensive insights. Jinapor, Suleman, and Cromwell (2023) showed that energy efficiency can directly and indirectly reduce environmental pollution in Africa. Their findings reveal that energy efficiency, particularly when combined with energy consumption, significantly lowers greenhouse gas emissions, especially compared to carbon and nitrous emissions. Notably, non-renewable energy harms the environment, while renewable energy promotes sustainability. Abid (2023) explored similar dynamics in Saudi Arabia from 1990 to 2019, finding that renewable energy use substantially reduces CO_2 emissions, with the effect strengthening at higher quantiles. In contrast, the negative impact of non-renewable energy on CO_2 emissions lessens as quantiles increase. Achuo, Miamo, and Nchofoung (2022) further supports these conclusions, showing that renewable energy usage improves environmental quality by reducing emissions, whereas non-renewable sources contribute to environmental degradation. These studies highlight the pivotal role of clean energy in sustainable development.

3 Theoretical Framework

To capture the impact of energy demand (END) on environmental quality, the study extends the simplified EKC model, according to Ulucak, and Bilgili, (2018). Financial access can influence the relationship between energy demand and environmental quality. Financial access may facilitate the adoption of cleaner technologies and improve energy efficiency.

Introducing financial access into the model as both a direct effect, and an interaction effect with energy demand.

$$EQ = \beta_0 + \beta_1 Y + \beta_2 Y^2 \quad (3.1)$$

Where; EQ represents environmental quality, Y represents income per capita, and $\beta 0$, $\beta 1$, $\beta 2$ are the parameters.

Extending the EKC model to capture the impact of energy demand on environmental quality;

$$EQ = \beta_0 + \beta_1 Y + \beta_2 Y^2 + \beta_3 END \quad (3.2)$$

Financial Access can influence the relationship between energy demand and environmental quality by facilitating the adoption of cleaner technologies and this will improve energy efficiency. Therefore, the study introduces financial inclusion into the model as both a direct effect, and an interaction effect with energy consumption

$$EQ = \beta_0 + \beta_1 Y + \beta_2 Y^2 + \beta_3 END + \beta_4 FIN\_ACCESS + \beta_5 END * FIN\_ACCESS \quad (3.3)$$

To understand the moderating effect of financial access, consider the partial derivative of environmental quality with respect to energy consumption:

$$\frac{\partial EQ}{\partial END} = \beta_3 + \beta_5 END \quad (3.4)$$

Here; β_3 represents the direct effect of END on environmental quality, β_5 represents how the effect of END on environmental quality changes with financial access. The sign and magnitude of $\beta 5$ indicate the moderating effect: If $\beta_5<0$, financial access mitigates the adverse impact of energy demand on the environment. If $\beta_5>0$, financial access exacerbates the adverse impact.

4. Research Design

4.1 Data Sources and Measurement

The study encompasses 38 out of the 46 Sub-Saharan African (SSA) countries, with the selection constrained by data availability. These 38 countries (listed in the appendix) are categorized into two income-based strata: low-income and middle-income economies. According to the World

Economic Outlook (2019) and the World Bank (2021/2022), low-income countries are defined as those with gross national income (GNI) per capita of $995 or less during the period 2015–2017, while middle-income countries exceed this threshold. The research makes use of yearly secondary data covering the years 2000–2021. Data on environmental quality (EQ), real gross domestic product (RGDP) energy demand (END), gross capital investment (GCI), financial access (FIN_ACCESS) and regulatory quality (REQ) were sourced from World Development Indicators (2022). The data on energy demand interaction with financial access was generated by the study

4.2 Model Specification

According to the Environmental Kuznets Curve (EKC) hypothesis, there exists an inverted U-shaped relationship between environmental degradation (commonly measured by CO_2 emissions) and per capita income. Initially, as income levels rise, environmental degradation increases. However, beyond a certain income threshold, environmental quality begins to improve as higher-income economies adopt cleaner technologies and implement environmental regulations (Dinda, 2004; Müller-Fürstenberger & Wagner, 2007; Kaika & Zervas, 2013).

Objective One: To investigate the relationship between energy demand and environmental quality in selected Sub-Saharan African economies, this study adapts and modifies the empirical model of Afolabi (2023). The model evaluates how energy demand, economic growth, regulatory quality, and capital investment influence environmental outcomes. The functional form of the model is specified as:

$$EQ = f(END, RGDP, REQ, GCI) \qquad 3.5$$

Where:

- EQ represents environmental quality, proxied by CO_2 emissions per capita,
- END is energy demand (proxied by fossil fuel energy use per capita),
- RGDP denotes real gross domestic product per capita (a proxy for economic growth),
- REQ refers to regulatory quality (measured in percentiles), and
- GCI indicates gross capital investment.

All variables, except REQ, are expressed in their natural logarithmic form to facilitate elasticity-based interpretation. The corresponding econometric equation is presented as:

$$\ln EQ_{(i,t)} = \beta_0 + \beta_1 \ln END_{(i,t)} + \beta_2 \ln RGDP_{(i,t)} + \beta_3 REQ_{(i,t)} + \beta_4 \ln GCI_{(i,t)} + \varepsilon_{(i,t)} \qquad 3.6$$

Here, *i* represents the cross-section of countries, *t* denotes the time period from 1991 to 2022, β_0 is the constant, β_1–β_4 are elasticity coefficients, and $\varepsilon_{(i,t)}$ is the error term.

Objective Two: To assess the moderating effect of financial access on the energy demand–environmental quality relationship, the study extends the baseline model by incorporating financial inclusion. This approach captures the conditional impact of financial access on how energy use affects environmental outcomes.

The extended functional form is given as:

$$EQ = f(END, Fin\_ACCESS, RGDP, REQ, GCI) \quad 3.7$$

The corresponding econometric model becomes:

$$lnEQ_{(i,t)} = \beta_0 + \beta_1 lnEND_{(i,t)} + \beta_2 lnFin\_ACCESS_{(i,t)} + \beta_3(lnEND_{(i,t)} \times Fin\_Access_{(i,t)}) + \beta_4 lnRGDP_{(i,t)} + \beta_5 REQ_{(i,t)} + \beta_6 lnGCI_{(i,t)} + \varepsilon_{(i,t)} \quad 3.8$$

Where:

- Fin_Access denotes the level of financial access (e.g., percentage of population with access to formal financial services),
- lnEND × Fin_Access is the interaction term representing the moderating influence of financial access on the energy-environment nexus.

To evaluate the total effect of energy consumption on environmental quality, accounting for the influence of financial inclusion, the partial derivative of the environmental quality function with respect to energy consumption is derived as follows:

$$\partial EQ_{(i,t)} / \partial ENd_{(i,t)} = \beta_1 + \beta_3 Fin\_Access_{(i,t)} \quad 3.9$$

The sign and magnitude of this expression inform the nature of the relationship:

- If $\beta_1 > 0$ and $\beta_3 < 0$, it suggests that energy demand negatively affects environmental quality, especially when financial access leads to greater adoption of inefficient energy technologies.
- If $\beta_1 < 0$ and $\beta_3 > 0$, this indicates that financial access supports the adoption of clean energy technologies, thereby improving environmental quality.
- A scenario where $\beta_1 > 0$ and $\beta_3 > 0$ implies that both energy demand and financial access positively reinforce improvements in environmental quality.

- Conversely, $\beta_1 < 0$ and $\beta_3 < 0$ suggests that both variables jointly amplify environmental degradation.

Furthermore, the sign of the total derivative ∂EQ/∂END reveals whether energy demand—either alone or when moderated by financial access—contributes positively or negatively to environmental outcomes in the selected Sub-Saharan African economies.

4.3 Estimation Technique

The unique Cross Sectional Autoregressive Distributed Lag (CS-ARDL) estimating technique created by Chudik et al. (2016) is the primary analytical method employed in this paper. Aspects of the Mean Group (MG) and Pool Mean Group (PMG) estimators can be incorporated into the CS-ARDL credited 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. Using the panel ARDL-PMG estimator, the validity of the CS-ARDL estimates is evaluated. Equations (3.1) in the panel ARDL version are expressed as;

$$\Delta y_{it} = w_i + \delta_i(y_{i,t-1} - \theta_i' x_{i,t-1}) + \sum_{j-1}^{p-1} \phi_{ij} \Delta y_{i,t-j} + \sum_{j-0}^{q-1} \alpha_{ij} \Delta x_{i,t-j} + \varepsilon_{it} \qquad 3.10$$

where y_{it} is environmental quality for economy i at time t; α_{ij} represents a matrix of the regressors (factors); θ_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 denotes in 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 (3.10) can be changed to be stated as its CS-ARDL equivalent, which is:

$$\Delta y_{it} = \mu_i + \delta_i(y_{i,t-1} - \theta_i' x_{i,t-1} + \delta_i^{-1} n_i \overline{y_t} + \delta_i^{-1} \varphi_i' \overline{x_t}) +$$
$$\sum_{j-1}^{p-1} \phi_{ij} \Delta y_{i,t-j} + \sum_{j-0}^{q-1} \alpha_{ij} \Delta x_{i,t-j} + \sum_{j-0}^{p-1} \tau_{ik} \Delta \bar{y}_{t-j} + \sum_{j-0}^{q-1} \Delta_{ik} \varphi \bar{x}_{t-j} + \varepsilon_{it} \qquad 3.11$$

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

The study 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). The CD test, which Pesaran (2004) first introduced, is described as:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho ij\right) \quad 3.12$$

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.

The study performed the panel unit root test after doing the slope homogeneity and CD testing. First-generation unit root techniques include Im, Pesaran and Shin (IPS) and Levin-Lin Chu, however they are unlikely to address CD problems (Wu et al., 2021). To determine the order of integration of each variable and take into consideration the observed cross-sectional dependence across the sampled nations, we used the second-generation cross-sectional augmented CADF and IPS (CIPS) by Pesaran (2007).

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.

In summary, Cross-Sectional ARDL is informed by the need to analyze dynamic relationships in panel data, considering heterogeneity and potential structural breaks. While it offers advantages in terms of dynamic modeling and heterogeneity consideration, researchers should be mindful of data requirements, model complexity, and potential challenges in interpretation.

5. EMPRICAL ANALYSIS AND DISCUSSION OF RESULT

Formal pre-estimation analysis and informal preliminary analysis are the two key steps of the traditional technique described in the literature that come before the estimation process. Within the framework of this research, the former comprises statistical summaries, descriptive analyses, and graphical displays of the data utilized. The next step in the preliminary analysis process is to check if the series being studied has any unit roots.

5.1 Descriptive Statistics

Table 2 presents the descriptive statistics that summarize the dataset employed in the analysis. It outlines key statistical measures for each variable, including the mean, maximum, minimum, and standard deviation. Additionally, it provides insights into the distributional characteristics of the variables through skewness and kurtosis metrics, while the Jarque-Bera (JB) test is employed to assess the normality of the distributions.

On average, the Real Gross Domestic Product (RGDP) across the sampled Sub-Saharan African economies is approximately US$4.37 trillion (in constant terms). Environmental quality (EQ), proxied by carbon emissions, records an average value of US$1.46 trillion. Per capita energy demand (END) shows a mean value of 40.807, while average financial access (FIN_Access) stands at 22.44%. Gross capital investment averages US$22.42, and the regulatory quality (REQ) is reflected by a percentile average of 31.01%.

The wide gap between the maximum and minimum values of the variables is reflected in the relatively high standard deviations, indicating substantial variability within the dataset. However, due to the differing units of measurement across variables, standard deviations were normalized to enable meaningful comparison. Notably, RGDP and EQ display the greatest volatility, evidenced by their relatively higher dispersion compared to other indicators.

From a distributional standpoint, most variables exhibit positive skewness, indicating a concentration of values to the left of the mean. The kurtosis values suggest that while many variables are leptokurtic—demonstrating heavier tails than the normal distribution—END displays a flatter (platykurtic) distribution, and REQ approximates a normal (mesokurtic) shape. Results from the Jarque-Bera test reveal that the null hypothesis of normal distribution is rejected at the 5% significance level for the majority of the variables, as indicated by p-values less than 0.05.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis	J-Bera
EQ	1178	26116.207	66604.472	0	448298.1	4.211	22.3265	2.20E+04
ENC	1178	40.807	29.462	1.64	99.978	0.64876	2.13998	118.9***
FIN INC	1178	22.4425	25.04785	0.0064215	142.422	2.205	7.5369	1965
RGDP	1178	4.37E+10	8.00E+10	7.16E+08	5.19E+11	3.290795	14.76335	8922***
GCI	1178	22.42	9.141	1.525	79.401	1.022744	5.724393	569.7***
REQ	1178	31.011	18.967	0.472	86.058	0.532	2.6642	61.13***

Source: Author's Computation (2024)

5.2 Correlation Analysis

To evaluate the strength and direction of relationships among the key explanatory variables, a correlation analysis was conducted. This step was essential in detecting any potential multicollinearity issues that could compromise the reliability of the regression estimates. The results, presented in Table 3, reveal generally moderate inter-variable associations. Among the variables, real GDP demonstrates the strongest positive correlation with carbon emissions, highlighting the link between economic activity and environmental impact. However, the absence of any excessively high correlation coefficients suggests that multicollinearity is not a concern in the model. Consequently, the inclusion of all selected independent variables is statistically appropriate and does not distort the model's estimations.

Table 3: Correlation Matrix

SSA						
Variables	-1	-2	-3	-4	-5	-6
(1) END	1					
(2) FIN_ACCESS	0.569	1				
(3) RGDP	0.323	0.335	1			
(4) GCI	0.073	-0.032	0.017	1		
(5) REQ	0.356	0.535	0.033	0.015	1	
(6) END_FIN_ACCESS	0.693	0.966	0.391	-0.004	0.528	1

Source: Author's Computation using Stata 15 (2024)

5.3 Cross-sectional Dependence

Due to the diverse structural and economic characteristics across the sampled countries, it is essential to examine the presence of cross-sectional dependence (CD) in the panel data analysis. The Pesaran CD test results, summarized in Table 4, reveal a statistically significant rejection of the null hypothesis of no cross-sectional dependence at the 1% level. This indicates that variations in key variables—such as environmental quality, energy consumption, real GDP, financial access, capital investment, regulatory quality, and the interaction term END_FIN_ACCESS—may have spillover effects across borders. In other words, developments in one country are likely to influence outcomes in others within the region. These findings highlight the degree of interdependence and shared economic and environmental dynamics among Sub-Saharan African economies.

Table 4: Cross-Sectional Dependence

Variable	Statistics
LEQ	95.86(0.000)
LEND	35.57(0.000)
LFIN_ACCESS	44.27(0.000)
LRGDP	124.11(0.0000)
LGCI	11.94(0.000)
REQ	4.51(0.000)
LEND*FIN_ACCESS	51.05(0.000)

Source: Author's Computation using Stata 15 (2024)

5.4 Analysis of The Unit Root

This section reports the results of unit root tests, which are essential for determining whether the variables in the model are stationary or non-stationary—an important step in conducting valid statistical inferences. To enhance reliability and ensure consistency, several unit root testing techniques are applied, including Pesaran's Cross-sectionally Augmented Dickey-Fuller (CADF) test, the Pesaran Panel Unit Root Test that accounts for cross-sectional dependence, and the Breitung test. Each method is executed under two scenarios: one assuming a constant only and another incorporating both a constant and a trend. The data series are logarithmically transformed for standardization, except for energy demand (END) and financial access (FIN_ACCESS), which are already in percentage form.

Following the cross-sectional dependence findings, it is critical to apply unit root tests suited for such data conditions. The CIPS and CADF tests introduced by Pesaran (2007) are specifically chosen for their effectiveness in addressing cross-sectional dependencies. As presented in Table 5, the outcomes show a mixed order of integration among the variables across the three models—some are stationary at level (I(0)), while others achieve stationarity only after first differencing (I(1)). This diversity in integration levels satisfies a necessary condition for implementing the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model. To further confirm these results, the Breitung unit root test is used as a supplementary measure. The detection of both stationary and non-stationary variables points to the likelihood of long-run relationships, thereby warranting a formal cointegration analysis in the subsequent section.

Table 5: The Combined First-and-Second Generation Unit Root Tests

Variable	**CADF**			**CIPS**			**Breitung**		
	Level	**First Diff**	**Order of Int**	**Level**	**First Diff**	**Order of Int**	**Level**	**First Diff**	**Order of Int**
LEQ	-1.16	-8.01***	I(1)	NA	NA		NA	NA	
ENC	-3.74***	-7.82***	I(0)	-2.43*	-5.28***	I(0)	0.57	-14.88***	I(1)
LFIN_INC	-3.74***	-11.68***	I(0)	-3.75**	-5.85***	I(0)	-6.48***	-11.35***	I(0)
LRGDP	-1.12	-4.58***	I(1)	-2.08**	-4.38***	I(0)	17.85	-10.68***	I(1)
LGCI	-3.48***	-9.08***	I(0)	-2.63*	-5.35**	I(0)	-4.26***	-16.23***	I(0)
REQ	1.64	-7.84***	I(1)	-2.12**	-5.62**	I(0)	-2.65***	-24.02***	I(0)
LENC*FIN_INC	-0.69	-11.58***	I(1)	-3.19**	-5.86**	I(0)	-5.20***	-11.39***	I(0)

Source: Author's Computation (2024) Stationary at 1% (*), 5% (**) and 10% (***)

5.5 Analysis of homogeneity slope

The homogeneity slope test is crucial in panel data analysis as it helps determine whether the relationships between variables are consistent across different groups or entities within the panel. Specifically, this test assesses whether the slope parameters of the regression model are uniform across all panel units. Overall, the homogeneity slope test is essential for ensuring the robustness and accuracy of panel data analysis results, ultimately enhancing the credibility of research findings and conclusions.

Before proceeding with panel data estimation, it is imperative to ascertain the status of slope parameters to prevent inconsistent estimators. Both Model A, which lacks an interactive term, and Model B, which includes an interactive term of energy demand and financial access, undergo the slope homogeneity test. The results presented in Table 6, derived from the slope homogeneity test proposed by Pesaran and Yamagata (2008), reject the null hypothesis that the slope parameters remain uniform across the panels. This outcome vividly illustrates the variability in slopes among the sampled nations. Consequently, it is evident that Sub-Saharan African nations exhibit differences in their levels of energy demand and environmental degradation (CO2), among other factors. Another implication of this finding is that Sub-Saharan African countries are not achieving convergence in their growth process because of their failure to achieve economic integration in the continent. This is in sharp contrast to the Asian countries that have achieved growth convergence driven by high level of economic integration among them.

Table 6: Testing for slope heterogeneity

	MODEL A		**MODEL B**	
	SH	**ASH**	**SH**	**ASH**
Value	38.164	42.502	20.981	34.812
Prob	0.000	0.000	0.000	0.000

Source: Author's Computation using Stata 15 (2024)

5.6 Analysis of Cointegration

The Westerlund (2007) second-generation cointegration test is widely regarded for its ability to uncover long-run equilibrium relationships in panel data, especially in the presence of cross-sectional dependence. Table 7 summarizes the results for both estimated models.

In Model A (excluding the interaction term), the modified Dickey-Fuller (DF) statistic stands at 3.6431, exceeding critical values and providing strong grounds for rejecting the null hypothesis of no cointegration. The accompanying p-value of 0.0001 reinforces this result, offering compelling statistical evidence of a stable long-run relationship among the model variables. On the other hand, the Augmented Dickey-Fuller (ADF) test returns a statistic of 1.4326, which is below conventional thresholds. While its p-value of 0.0760 does not meet the standard 5% significance level, it still suggests a marginal indication of cointegration, though not conclusively.

In Model B (which includes the interaction term between energy consumption and financial access), the modified DF test once again affirms long-term association, yielding a test statistic of 3.8243 and a highly significant p-value of 0.0001. The ADF test further supports this outcome, producing a statistic of 2.2185 with a p-value of 0.0133, which falls well below the 5% significance mark, indicating statistical significance.

In summary, the findings from both models strongly suggest the presence of cointegration. This confirms that over time, variables such as environmental quality, energy demand, real GDP, financial access, and capital investment exhibit long-term co-movement and equilibrium relationships in the context of Sub-Saharan African economies.

Table 7: Cointegration Test

	MODE A		**MODE B**	
	t-Statistics	**p-value**	**t-Statistics**	**p-value**
Mod_DF	3.6431	0.00001	3.8243	0.0001
DF	1.3526	0.0881	2.2094	0.0136
ADF	1.4326	0.076	2.2185	0.0133
Unadj Mod_DF	2.0132	0.022	2.1396	0.0162
Unadj DF	-0.6601	0.2546	0.0433	0.4827

Source: Author's Computation using Stata 15 (2024

6. Discussion of Empirical Results

The environmental quality–energy demand model, is estimated with the variables expressed in logarithmic form. This decision aligns with the recommendation made by Cole et al. (1997), who argued in favor of estimating models using logarithmic transformations. Recent studies, such as Acheampong (2018) have also followed this approach when estimating the CO2–energy consumption model. Therefore, the empirical estimates presented in this study are based on the log-linear version of the CO2–energy consumption model.

6.1 Environmental Quality and Energy Demand Relationship

Drawing on insights from the preliminary diagnostics, the CS-ARDL model is employed to explore in greater depth the link between energy demand and environmental quality across Sub-Saharan African nations—addressing the first objective of this study. The estimation results are summarized in Table 8, displaying both long-run and short-run dynamics.

The findings reveal that energy demand has a statistically significant negative effect on environmental quality, both in the short and long term. This outcome implies that rising energy demand—driven by industrial and domestic activities—intensifies carbon emissions and contributes to environmental degradation. The implication is that energy use, as currently structured, exacerbates ecological harm in the region and may hinder sustainable development if not addressed.

Additionally, the results show that both real GDP (RGDP) and gross capital investment (GCI) are positively associated with carbon emissions in the selected SSA countries. This relationship reflects the ongoing industrial expansion within these economies. Such evidence supports earlier findings by Baz et al. (2020), Faruq (2019), Adejumo (2019), and Salahuddin & Gow (2019), who reported similar patterns where economic growth and capital investments spurred energy demand but also led to increased environmental pollution in countries like Pakistan, Nigeria, and Qatar.

Moreover, the analysis finds that the quality of environmental regulation (REQ) consistently shows a negative relationship with CO_2 emissions, highlighting the importance of effective environmental governance. This suggests that robust enforcement of environmental policies can play a pivotal role in reducing emissions and promoting ecological sustainability. As echoed by Hassan et al. (2020), adopting green policies and ensuring regulatory compliance are vital steps toward improving environmental quality in the Sub-Saharan African context.

Lastly, the error correction term (ECT) indicates a relatively slow adjustment rate to long-run equilibrium following short-term disruptions, suggesting that the recovery process from environmental or economic shocks is gradual across these economies.

Table 8: CS-ARDL Estimates on Environmental Quality and Energy Consumption Relationship

D.LEQ	Coef.	Std.Err.	Z	P>z
ECT	-1.286***	0.037	-34.56	0
	Short Run Est.			
LEQ(-1)	-0.286***	0.037	-7.68	0
END	0.021**	0.009	2.27	0.023
LRGDP	0.137	0.178	0.77	0.441
REQ	0.163*	0.092	1.77	0.077
LGCI	-0.004	0.029	-0.14	0.888
	Long Run Est.			
END	0.015**	0.006	2.38	0.017
LGCI	-0.004	0.023	-0.15	0.877
REQ	0.139*	0.076	1.83	0.067
LRGDP	0.059	0.133	0.45	0.655
LGCI	0.007	0.047	-0.15	0.884

Source: Author's Computation using Stata 15 (2024) Note: *p < 0.1, **p < 0.05, ***p < 0.01

6.2 The Role of Financial Access on the Nexus between Environmental Quality and Energy Demand

Ozili (2023) posits that enhancing financial inclusiveness can significantly contribute to environmental improvement, particularly in non-EU regions. In line with this, the study incorporates an interaction term between energy demand (END) and financial access (FIN_ACCESS) to explore their joint effect on environmental quality. The findings, as displayed in Table 9, reveal that in the short term, FIN_ACCESS has a positive yet statistically insignificant impact on environmental quality across Sub-Saharan Africa. However, in the long run, this relationship turns both positive and statistically significant. This indicates that greater access to financial services ultimately reduces carbon emissions, thereby fostering better environmental outcomes over time.

Delving deeper into the moderating effect of financial access on the energy-environment nexus, the analysis reveals that FIN_ACCESS significantly dampens the negative impact of energy consumption on environmental quality in both the short and long run. This implies that broader financial inclusion can act as a mitigating force, curbing the environmental harm typically associated with rising energy use. The findings underscore the strategic role of financial sector expansion in advancing environmental sustainability within SSA economies.

These results are in harmony with earlier studies by Ike et al. (2020), who found that financial inclusion lessens the detrimental effects of CO_2 emissions in both developing nations and G-7 countries. The implication is clear—policy frameworks in SSA should prioritize financial inclusion as a lever for enhancing environmental protection.

In addition, the analysis shows that real GDP—used as a proxy for economic growth—negatively impacts environmental quality in both timeframes. This aligns with theoretical expectations and supports findings by Afolabi (2023) who observed that economic expansion often correlates with increased energy consumption and greenhouse gas emissions. In the context of SSA, rapid economic growth, particularly during the early 2000s, has been accompanied by rising pollution levels due to intensified industrial activity and economic diversification.

Therefore, while economic transformation remains a critical objective, these insights highlight the pressing need for SSA nations to pivot towards sustainable energy solutions. Embracing renewable and cleaner energy sources will be crucial in balancing development goals with environmental preservation as the region continues to industrialize.

Table 9: CS-ARDL Estimates on the Role of Financial Access on the Nexus between Environmental Quality and Energy Demand

D.LEQ	Coef.	Std.Err.	Z	P>z
	FULL SAMPLE			
ECT	-1.327***	0.069		0.000
	Short Run Est.			
LEQ(-1)	-0.327***	0.069	-4.75	0.000
END	0.122*	0.073	1.69	0.092
FIN_ACCESS	0.044	0.379	0.12	0.308
END*FIN_ACCESS	-0.006	0.006	-1.02	0.308
LRGDP	0.398*	0.208	1.93	0.053
REQ	0.052	0.073	0.72	0.474
LGCI	-0.029	0.057	-0.51	0.609
	Long Run Est.			

ENC	0.156	0.072	2.16	0.031
FIN_ACCESS	0.336	0.338	1	0.019
END*FIN_ACCESS	-0.016*	0.01	-1.65	0.099
LGCI	0.142	0.133	1.07	0.286
REQ	0.067	0.063	1.07	0.285
LRGDP	0.881***	0.547	1.61	0.007

Source: Author's Computation using Stata 15 (2024) Note: *p < 0.1, **p < 0.05, ***p < 0.01

6.3 Robustness Checks: ARDL (PMG) Estimate on the Nexus of Environmental Quality and Energy Demand

In the context of panel data analysis, a range of estimation challenges can undermine the validity of empirical findings. Therefore, performing robustness checks is essential to confirm the reliability and stability of results. To this end, the study applies the Pooled Mean Group (PMG) estimator as an alternative technique. Table 10 presents the re-estimated outcomes for addressing the first and second research objectives using this method.

The PMG estimation results reinforce the core findings from earlier analyses, showing a statistically significant and positive association between energy demand and carbon emissions in both the short term and the long term. This relationship underscores the detrimental environmental consequences of rising energy usage—whether in households or industrial sectors—across Sub-Saharan Africa, as it leads to elevated carbon emissions and deteriorating environmental quality over time.

Moreover, the analysis reveals that both real GDP (RGDP) and gross capital investment (GCI) exhibit positive elasticities with carbon emissions. This pattern reflects the environmental costs of economic development, where intensified industrial and investment activity contributes to environmental degradation. These findings align with those of Baz et al. (2020) in Pakistan and are corroborated by Mesagan and Olunkwa (2020), who found a strong link between capital investment and carbon emissions in Algeria, Nigeria, and Morocco. The evidence suggests that while capital accumulation is pivotal for economic growth, it also poses a significant threat to environmental sustainability—highlighting a clear trade-off between progress and preservation.

Table 10 (with interactive term) also examines the moderating role of financial inclusion in the energy-environment relationship. Consistent with the outcomes in Table 9, the interaction between financial access and energy demand shows a negative and statistically significant effect on carbon emissions in both timeframes. This implies that broader financial access helps to cushion the adverse environmental effects of rising energy demand, enhancing environmental quality in the long run. These results indicate that financial inclusion plays a crucial role in shaping energy consumption's environmental impact in the Sub-Saharan African context.

Additionally, the findings reaffirm the importance of regulatory quality, which exhibits a significant inverse relationship with carbon emissions over both the short and long term. This suggests that effective regulatory frameworks and their enforcement can substantially curb emissions and foster a healthier environment. Accordingly, the study highlights the urgent need for Sub-Saharan African nations to strengthen green policy frameworks and ensure strict adherence to environmentally sound regulations. Echoing the argument of Hassan et al. (2020), embedding sustainability through policy and legislation is vital to reversing the current trajectory of environmental degradation in the region.

Table 10: Robustness Checks using ARDL (PMG) Estimate on the Nexus of Environmental Quality and Energy Consumption

D.LEQ	**Without Interactive**		**With Interactive**	
	Coef.	**Std.Err.**	**Coef.**	**Std.Err.**
ECT	-0.097	0.003	-0.094	0.028
Short Run Est				
ENC (-1)	0.036***	0.013	0.036**	0.016
FIN_INC (-1)			-0.002*	0.006
LENC*FIN_INC (-1)			0.136	0.105
LRGDP (-1)	0.553***	0.104	0.549***	0.123
REQ (-1)	0.062	0.057	0.03	0.034
LGCI (-1)	-0.042*	0.022	-0.027	0.018
Cons	0.264	0.068	0.244	0.091
Long Run Est				
ENC	0.023***	0.003	0.056***	0.004
FIN_INC			0.036***	0.004
LENC*FIN_INC			-0.694***	0.073
LRGDP	0.224***	0.049	0.349***	0.042

REQ	-0.105***	0.033	-0.134***	0.027
LGCI	0.11**	0.053	0.013	0.046

Source: Author's Computation using Stata 15 (2024) Note: *p < 0.1, **p < 0.05, ***p < 0.01

7. CONCLUSION AND RECOMMENDATIONS

The study reveals that rising energy demand significantly contributes to increased carbon emissions in both the short and long term, indicating a strong link between energy consumption and environmental degradation in Sub-Saharan Africa. Similarly, real GDP and gross capital investment are positively associated with emissions, highlighting that industrialization and infrastructure development, exacerbate environmental harm. These developments often occur without adequate environmental safeguards, intensifying pollution. Conversely, environmental regulations show a negative relationship with emissions, implying that effective policy enforcement can improve environmental quality.

Excessive reliance on fossil fuels and the underuse of renewable energy are key drivers of environmental degradation. Addressing these issues requires a deliberate shift toward greener energy alternatives. The findings challenge the applicability of the Environmental Kuznets Curve (EKC) theory in this context, arguing that it may not fully capture the region-specific dynamics of financial inclusion, energy use, and environmental quality. Overall, the study offers valuable insights into the interplay between economic growth and environmental sustainability in SSA. It underscores the importance of region-specific frameworks and institutional reforms to manage the trade-offs between growth and environmental protection. By adopting these insights, policymakers can work toward a sustainable development path that balances progress with ecological preservation.

Given that financial access has a significant moderating influence on the negative effects of energy consumption on environmental quality, policymakers in SSA should give priority to programs that increase financial service accessibility, especially in disadvantaged and rural areas. To drive further financial inclusion and promote environmental sustainability, deliberate policies to promote microfinance institutions, mobile banking, and digital payment systems.

Adopting sustainable energy practices, such as making investments in renewable energy sources like solar, wind, and hydroelectric power, should be a top priority for governments and corporations. Authorities in these countries need to encourage financial institutions to offer green financing options that support environmentally sustainable projects and initiatives. This could include funding for renewable energy projects, energy-efficient technologies, and ecofriendly infrastructure development. Provide incentives for households and businesses in these countries to invest in environmentally sustainable projects. This could include tax breaks, subsidies, or grants for investments in renewable energy, energy efficiency, and other green initiatives.

References

Abid, M. (2023). How Does Renewable Energy Consumption Affect Environmental Quality in Saudi Arabia? Evidence from Quantile Regressions. *International Journal of Energy Economics and Policy*, *13*(4), 574.

Acheampong, A. O. (2018). Economic growth, CO2 emissions and energy consumption: What causes what and where? Energy Economics, 74, 677-692.

Acheampong, A. O., & Dzator, J. (2020). Managing environmental quality in sub-Saharan Africa: Does institutional quality matter? In *Handbook of environmental materials management*. Springer.

Achuo, E. D., Miamo, C. W., & Nchofoung, T. N. (2022). Energy consumption and environmental sustainability: What lessons for posterity?. *Energy Reports*, *8*, 12491-12502.

Adejumo, O. O. (2020). Environmental quality vs economic growth in a developing economy: complements or conflicts. *Environmental Science and Pollution Research*, *27*(6), 6163-6179.

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.

Ahmad M, Satrovic E. Relating fiscal decentralization and financial inclusion to environmental sustainability: criticality of natural resources. J Environ Manag 2023;325:116633.

Ang, J. B. (2007). "CO_2 emissions, energy consumption, and output in France." *Energy Policy*, 35(10), 4772-4778.

Asafu-Adjaye, J. (2003). Biodiversity Loss and Economic Growth: A Cross-Country Analysis. *Contemporary Economic Policy*, *21*(2), 173-185.

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.

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.

Cole, M. A. (2004). Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. *Ecological economics*, *48*(1), 71-81.

Cole, M. A., Rayner, A. J., & Bates, J. M. (1997). The environmental Kuznets curve: an empirical analysis. *Environment and development economics*, *2*(4), 401-416.

Damrah S, Satrovic E, Shawtari FA. How does financial inclusion affect environmental degradation in the six oil exporting countries? The moderating role of information and communication technology. Front Environ Sci 2022;10: 1–17.

Demirguc-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). "The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution." World Bank

Dinda, S. 2004. Environmental Kuznets curve hypothesis: a survey. *Ecological economics*, *49*(4), 431-455.

Eslami H, Najem S, Abi Ghanem D, Ahmad A. The potential of urban distributed solar energy in transition economies: the case of Beirut city. J Environ Manag 2021;285:112121.

Fareed Z, Rehman MA, Adebayo TS, Wang Y, Ahmad M, Shahzad F. Financial inclusion and the environmental deterioration in Eurozone: the moderating role of innovation activity. Technol Soc 2022;69:101961.

Faruq Umar, Q. (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*, 6(2), 169-179.

Feng L, Palmer PI, Zhu S, Parker RP, Liu Y. Tropical methane emissions explain large fraction of recent changes in global atmospheric methane growth rate. Nat Commun 2022;13:1–18. https://doi.org/10.1038/s41467-022-28989-z.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement.

Ike, G. N., Usman, O., & Sarkodie, S. A. (2020). Testing the role of oil production in the environmental Kuznets curve of oil producing countries: New insights from Method of Moments Quantile Regression. *Science of the Total Environment*, *711*, 135208.

Jinapor, J. A., Suleman, S., & Cromwell, R. S. (2023). Energy Consumption and Environmental Quality in Africa: Does Energy Efficiency Make Any Difference? *Sustainability*, *15*(3), 2375.

Kahia, M., Jebli, M. B., & 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*(4), 871-885.

Le, T. H., Lee, J., & Ho, H. M. (2020). "Institutional quality, economic development, and environmental degradation: Evidence from a global perspective." *Environmental Science and Pollution Research*, 27(18), 23234-23247.

Liu N, Hong C, Sohail MT. Does fnancial inclusion and education limit CO2 emissions in China? A new perspective. Environ Sci Pollut Res 2021. https://doi. org/10.1007/s11356-021-17032-1.

Mesagan, E. P., & Olunkwa, C. N. (2020). *Energy consumption, capital investment and environmental degradation: the African experience* (No. WP/20/022). AGDI Working Paper.

Müller-Fürstenberger, G., and Wagner, M. 2007. Exploring the environmental Kuznets hypothesis: Theoretical and econometric problems. *Ecological Economics*, *62*(3-4), 648-66

Musah M. Financial inclusion and environmental sustainability in Ghana: application of the dynamic ARDL estimator. Environ Sci Pollut Control Ser 2022; 29:60885–907. https://doi.org/10.1007/s11356-022-19994-2.

Ozili, P. K. (2023). Impact of monetary policy on financial inclusion in emerging markets. *Journal of Risk and Financial Management*, *16*(7), 303.

Park, C. Y., & Mercado, R. (2015). Financial inclusion, poverty, and income inequality in developing Asia. *Asian Development Bank Economics Working Paper Series*, (426).

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.

Rehman AU, Malik AH, Md Isa AHb, Jais Mb. Dynamic impact of financial inclusion and industrialization on environmental sustainability. Soc Responsib J 2022. https://doi.org/10.1108/SRJ-07-2021-0275. ahead-of-print No. ahead-ofprint.

Renzhi N, Baek YJ. Can financial inclusion be an effective mitigation measure? Evidence from panel data analysis of the environmental Kuznets curve. Finance Res Lett 2020;37:101725. https://doi.org/10.1016/j.frl.2020.101725.

Saidi K, Hammami S. Economic growth, energy consumption and carbon dioxide emissions: recent evidence from panel data analysis for 58 countries. Qual Quantity 2015. https://doi.org/10.1007/s11135-014-0153-1.

Salahuddin, M., & Gow, J. (2019). Effects of energy consumption and economic growth on environmental quality: evidence from Qatar. *Environmental Science and Pollution Research*, *26*(18), 18124-18142.

Shahbaz M, Li J, Dong X, Dong K. How financial inclusion affects the collaborative reduction of pollutant and carbon emissions: the case of China. Energy Econ 2022;107:105847.

Soytas, U., Sari, R., & Ewing, B. T. (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics*, *62*(3-4), 482-489.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World development*, *32*(8), 1419-1439.

Ulucak, R., & Bilgili, F. (2018). A reinvestigation of EKC model by ecological footprint measurement for high, middle and low income countries. *Journal of cleaner production*, *188*, 144-157.

Usman M, Balsalobre-Lorente D, Jahanger A, Ahmad P. Pollution concern during globalization mode in financially resource-rich countries: do financial development, natural resources, and renewable energy consumption matter? *Renewable Energy.* 2022;183:90–102. doi: 10.1016/j.renene.2021.10.067

World Development Indicators (2021). *The World Bank, Databank.* Available at: http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators. Accessed July 9th, 2021.

Yang M, Yaru H, Wang Q. Rethinking on regional CO2 allocation in China: A consideration of the carbon sink. Environ Impact Assess Rev 2022;96:106822. htt ps://doi.org/10.1016/j.eiar.2022.106822.

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