FWU Journal of Social Sciences, Summer 2024, Vol.18, No.2, 78-90
DOI: http://doi.org/10.51709/19951272/Summer2024/8

Green Finance and Sustainable Development Nexus in Sub-Saharan Africa

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This study comprehensively assesses the influence of green finance on sustainable development in sub-Saharan African countries from 1999-2023. The sub-Saharan African countries are considered most vulnerable to climate change due to their individual countries' geographical location, economic structure, population density, limited adaptive capacity to climate change, and social vulnerability. By examining the intricate linkages between green finance measured by financial development indicators, and institutional frameworks, technology, urbanization, and educational levels, the study aims to address environmental, social, and economic challenges and the trajectory of green development in sub-Saharan African countries. The pool mean group autoregressive distributed lags (PMG/ARDL) method was employed for its ability to rheostat endogeneity and serial autocorrelation, neglected by previous studies. The findings underscore the pivotal role of green finance, proxied by bank credit to the private sector, in promoting sustainable practices, through technological advancements and educational levels to increase investment in industries that prioritize sustainability, conservation, and biodiversity preservation. The negative nexus between foreign direct investment and the potential adverse consequences is associated with the influx of multinational corporations to sub-Saharan African countries, particularly due to lax environmental regulations linked to weak regulatory frameworks. In light of these findings, this study recommends aligning investments with sustainable development goals, enhancing regulatory oversight to improve environmental quality, and balancing economic growth and environmental stewardship through sustainable development strategies, given their countries' vulnerability to climate change.

***Keywords*:** CO2 emissions, financial development, environment quality, greenhouse emission, economic growth

JEL CLASSIFICATION: O13; O16; GO; Q5; 6F64

The sustainability of Sub-Saharan Africa (SSA) financial and economic sectors, particularly after the 2020 recession induced by the Covid-19 (coronavirus) and the economic and financial crisis induced by the Russian invasion of Ukraine in 2022, places the sustainable development of the extremely diverse and environmentally degraded region at the forefront of global discussions on green finance and sustainable development (Udoh, et al., 2023; Udo et al., 2023). According to Peng and Zheng (2021), green finance embraces access to affordable, convenient, and flexible financial services for investment, development, protection, and promotion of sustainable operational and business activities that rejuvenate environmental quality and optimize resource usage (Xie et al., 2020).

Access to affordable, convenient, and flexible green financial services is a fulcrum for ecological development through the adoption of energy-efficient equipment for poverty alleviation through green product awareness for farmers to cultivate green and organic crops (Wang & Zheng, 2020). The development and stability of the green economy anchor the simultaneous implementation of green policy adoption across sectors of the economy. Green finance integration into ecological and environmentally safe projects, especially in rural areas in

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SSA countries, is crucial because of the negative effects of climate change on the sustainability of the local economy due to environmental degradation.

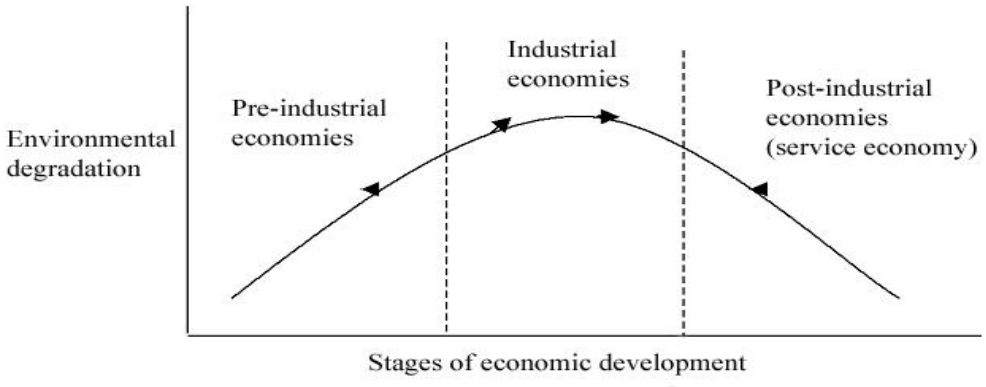
Environmental degradation not only stimulates health risks but also depletes resources and increases natural cataclysms through excessive reliance on fossil fuels; toxic emissions from vehicles; industrial waste; deforestation; and human operational and business activities in the agricultural, transportation, manufacturing, and energy production sectors (Udo, et al., 2023; Abner, 2023; Udo et al., 2024).

The increasing green energy supply-demand gap and escalating consumption of fossil fuel energy in SSA countries, where seven of the ten countries most vulnerable to climate change are in Africa, in the last two decades can be attributed to a lack of access to affordable energy. In SSA countries (excluding South Africa), the average energy consumption per capita is 180 kWh, while in the United States 13,000 kWh and 6,500 kWh in Europe. Access to green and affordable energy in the 21st century is considered a global fulcrum for sustainable economic and financial development and reduction in death rate annually due to fossil fuel energy, among others.

The growth of renewable energy potential in Africa and the stability of the economy at the primary stage of development, according to Patrick (1966) and Udo et al., (2019), is driven by the financial sector as the economy expands, and financial sector stability anchors on economic development and resourceful management system, for economies with limited financial resources to achieve maximum productivity, which stimulates economic growth (Furuoka, 2015), attracts investors, nurtures Foreign Direct Investment (FDI) inflows, boosts financing network deepening, reduces financial costs, and encourages industrial borrowing to increase green economic and financial stability through green production lines (Enoch, 2023; Udo, et al., 2023).

The financial-economic development nexus is explained by the Environmental Kuznets Curve (EKC), which posits that borrowing from the financial sector to enhance economic and financial stability through non-green industrial sector consuming fossil fuels reduces environmental quality. Similarly, structural financial and economic development posits that as the financial system and economy transit from a pre-industrial to an industrial stage of growth, environmental quality deteriorates due to fossil fuel energy consumption. In contrast, the transition from an industrial to a post-industrial economy improves environmental quality through green energy consumption (Figure 1). Theoretically, the need for increased emphasis on environmental quality and sustainable development is underscored.

Figure 1: The shape of the EKC



Source: Panayotou (2003:46)

The theoretical emphasis on environmental quality and sustainable development according to Enoch (2023), Haseeb et al., (2018), Shahbaz et al., (2018), and Udo et al., (2019), is evident in the profound financial shocks of the 2008-09 financial crisis on the entire economic system, raises the crucial question: on the extent of financial development influence on environmental degradation? Empirically, Tamazian and Rao (2010) argue that ecological degradation is regulated by institutional quality and financial development. Globally, African countries contribute approximately 4% of global greenhouse gas emissions at 1.45billion tonnes.

On a per capita basis, Africa accounts for an average of one ton of CO2 emitted annually by each individual. Notwithstanding the lowest emissions from Africa, seven of the ten countries most vulnerable to climate change are in Africa. In a bid to ease the adverse effect of CO2 emissions on ecological quality and stimulate sustainable development through increased access to green energy consumption across SSA countries by 2050 and in reaction to the pulling out from the Paris Agreement in 2017 by the United States', SSA countries have developed models to achieve zero emission by 2060 and tackle ecological challenges by projecting about $2.9 trillion of cumulative capital and expenditure in green-energy sources development. The Africa Climate Summit (ACS) report of 2023 revealed that regardless of Africa accounting for approximately 40% of the world's green energy resources, African countries have only access 2% ($ 60 billion) of the US$ 3 trillion green energy investments funds in the last decade.

The outbreak and exponential growth in COVID-19 cases in SSA countries and the ripple effect of the strictly imposed safety protocol of social distancing and lockdown to curtail the spread of COVID-19 for months induced the 2020 recession in SSA countries. The Russian invasion of Ukraine in 2022 is not without the economic and financial implications for the recovering SSA economy. These factors make SSA countries an apt scope for this study as a result of various climate change challenges, diminishing growth and development of SSA economies.

Previous studies of Ayesha et al., (2021); Ntow- Gyamfi et al., (2020); Nasir et al., (2019); Gorus and Aslan (2019); Haseeb et al., (2018), and Park et al., (2018) examining green finance and sustainable development nexus in developed and developing economies and economic bloc predominantly adopted the classical regression model, a single indicator of financial development. These studies focused on developed economies emitting from 50% to 80% of greenhouse gas into the atmosphere, ignoring SSA countries emitting 4% of greenhouse gas. Yet, seven of the ten most vulnerable countries to climate change are in Africa.

The extensive use of classical regression analytical models and the validity of research findings have raised questions in the empirical literature. Gunst and Mason (1980; 169–206) argued that inferences drawn based on a unique model are statistically suspicious. The adoption of a diverse paradigm to investigate this nexus, according to Udo et al., (2023), provides vital policy formulations and frontiers for this study. However, time-series data are skewed and leptokurtic (Brooks 2014). The spikes and variations render the regression model inappropriate for an accurate and reliable assessment of this link.

It is against this lacuna that this study delves into the dynamic interplay between financial development, environmental quality, and governance quality in selected SSA countries of Rwanda (GDP Growth: 6.2%), Côte d'Ivoire (GDP Growth: 6.2%), Benin (GDP Growth: 5.5%), Uganda (GDP Growth: 5.4%), Tanzania (GDP Growth: 5.2%), Kenya (GDP Growth: 5%), Togo (GDP Growth: 4.6%), Senegal (GDP Growth: 4.1%), Madagascar (GDP Growth: 4%), and Algeria (GDP Growth: 3.8%) considered in 2023 as stable and fastest-growing economies after the covid-19 pandemic from to 1999-2022.

This study measured green finance using the decomposed indicators of financial sector: openness (Foreign Direct Investment); efficiency (credit to the private sector) and market size (stock market capitalization); environmental quality is proxied by energy use, CO2 emissions, greenhouse emissions, natural resource depletion, and institutional quality proxied government effectiveness to examine the individual effect disregarded by previous studies. The use of these financial development indicators to measure green finance revealed the extent and depth of investments and financial activities directly linked to environmental sustainability and these indicators reflect not only monetary flows but also broader trends in sustainable development, technology adoption, and market dynamics. By aligning financial resources with green objectives, countries and businesses transit towards a more sustainable and resilient economy.

The pooled mean group autoregressive distributed lag model (PMG-ARDL) was adopted to explore the multifaceted green finance and sustainable development nexus and for its ability to control for endogeneity and serial autocorrelation, which previous studies ignored. The results of this study contribute to the extant literature by providing multiple practical implications, a policy development guide for the finance sector, and evidence of the influence of green finance on environmental sustainability. The study findings reveal that institutional quality, technology, education, and civilization influence and prevent environmental degradation and increase environmental quality through awareness of the benefits of green energy. The findings of this study further stress

the need for institutional reforms to reduce GHG and CO2emissions, natural resource depletion, and investment and development of greener SSA economies.

Literature Review

The sustainability of the financial sector is crucial for facilitating businesses' access to convenient, affordable, and flexible financial resources and providing investment opportunities for individuals (Ji et al., 2021). In light of the growing adverse effects of climate change on ecological quality induced by the increased consumption of fossil fuels, which increases CO2 emissions, GHG emissions, and depletes natural resources globally, particularly in SSA countries, the need to embrace green financing as a traditional financing option becomes inevitable (Kim et al., 2020; Enoch, et al., 2023; Abner, et al., 2023; Udo, et, al 2023; Udo, et, al 2024). As investors progressively and consistently acknowledged the environmental benefits associated with green energy and green financing to reduce credit risk and business volatility (Umar, Ji, Mirza, & Naqvi, 2021). Ji et al., (2021) revealed that green financial assets outperform non-environmentally responsive assets in for the BRICS economies. The dynamic evolution in the nexus between the finance environment over the decades is explained theoretically by the EKC model, which posits a U-shaped curve. The EKC model posits that countries, principally in their initial stages of development, ignore environmental conservation due to the cost implications associated with green energy development and prioritize policies aimed at stimulating economic development as countries stabilize towards sustainable development, natural resource conservation, and green energy development; a U-shaped curve depicting the link between income and the environment is established. Dinda (2004) argues that economies begin to explore environmentally friendly solutions because of concerns associated with environmental quality.

Theoretically, the link between financial development and environmental quality is explained by two hypotheses: The Pollution Haven Hypothesis (PHH), postulated by Peter Neary and Gene Grossman in the early 1990s, and the Pollution Halo Hypothesis (PH), postulated by Ramanathan and Collins in the late 1990s. The PHH posits that environmental regulations and stringent standards in developed countries lead to the migration of polluting multinational corporations (MNCs) to countries with lax environmental regulations and stringent standards, particularly developing countries. The validation of this hypothesis is that MNCs seeking profit margin improvement and production cost minimization migrate to countries where environmental regulations and compliance are lax, creating "pollution havens."

This is evident in Africa, where seven of the ten countries most vulnerable to climate change are found. The findings of Mensah et al., (2020), Enoch (2023), Shahbaz et al., (2018), among others, support the PHH argument that financial sector development diminishes environmental quality through industrialization and expansion of infrastructure, while investment and consumption of green energy improve environmental quality. It has been argued that the financial sector funds most economic activities, and these activities impair environmental sustainability.

Empirically, Afzal et al., (2023), Basit, et al., (2021); Enoch et al., (2023), Marrasso et al., (2019), and others revealed that financial development influences ecological quality through economic growth, attracting Foreign Direct Investment (FDI), and increasing energy consumption; flourishing financial markets provide credit to consumers, which increases demand for energy-intensive products and subsequent pollution, and financial development increases the financial capacity of firms consuming fossil energy, which contributes to environmental deterioration.

On the divergent, the PH argues that the migration of MNCs from countries with efficient, eco-friendly technologies and high environmental awareness contributes to CO2 emission reduction in host countries because their operational structure relies on green technology. Musah et al., (2021) Shahbaz et al., (2018) upheld the argument of proponents of the Pollution Halo Hypothesis. Based on these findings, we hypothesize a curvilinear nexus between financial development and environmental quality (H_1).

This study explores the role of institutional frameworks in prompting the financial development and environmental sustainability nexus to expand the frontiers of previous studies in developed and emerging economies. Strong and high-quality institutional frameworks advocate for laws and regulations promoting greener development. The findings of Ntow-Gyamfi et al., (2020) in Africa support fiscal policies and institutional quality in promoting climate-friendly investment options.

Based on these findings, the study assesses the nexus between institutional quality and environmental degradation in the selected SSA countries (H_2).

The impact of global milestones, such as the Paris Climate Conference and the United Nations' Sustainable Development Goals (SDGs), on environmental welfare is considered in this study. These global initiatives promote investment in sustainable business models and highlight the significance of green energy development for pollution decline (Ji et al., 2021; Taghizadeh-Hesary & Yoshino, 2020; Abner et al., 2023; Basit, et al., 2021; Enoch et al., 2023; Udo, et, al 2024). The advent of the Covid-19 pandemic and its ripple effect on the $105 trillion global economy and the $3.1 trillion African economy and financial markets revealed the impact of environmental quality on sustainable development. As such, lockdowns during the pandemic temporarily reduced CO2 emissions by 45% through the suspension of business and economic activities, particularly in the transportation and industrial sectors (Tollefson, 2021; Hadi, 2019; Nundy et al., 2021).

Relaxation of the lockdown led to a geometric increase in CO2 emissions due to production increase in industries consuming fossil fuel energy. Investment in green projects through the financial sector improves environmental quality. Recently, investment in green projects has significantly improved environmental quality, financial flexibility, and stability through the inflow of FDI from eco-friendly investors. These factors, among others, justify this study in the context of SSA countries, where seven of the ten countries most vulnerable to climate change are found. The theoretical underpinning and review of related literature provides a comprehensive overview of the evolving finance and environmental nexus. This study contributes to the extant literature by exploring the curvilinear financial development and environmental quality nexus and assessing the influence of institutional quality on this nexus in selected SSA countries considered in 2023 by the World Bank as stable and fast-growing economies after the COVID-19 pandemic. In addition, this study considers the impact of global initiatives on environmental sustainability.

Method

The annualized time series dataset was collated from Word Bank Indicators (2022) for a sample size of 10 SSA heterogeneous cross-sections for 25 periods from 1999 to 2023 was adopted using the *ex-post facto* research design. These countries are considered by the World Bank in 2023 to be stable and fast-growing economies after the COVID-19 pandemic, with gross domestic product growth between 6.2% and 3.8% of the population of 47 SSA countries recognized by the World Bank. Table 1 shows the sample population, with a GDP growth rate of 2023.

The panel model was adopted to account for the heterogeneity of the individual SSA countries. This study decomposes financial sector development into sub-indices of openness (Foreign Direct Investment) efficiency (bank credit to the private sector) and market size (stock market capitalization), environmental quality is proxied by energy used, CO2 emissions, greenhouse emissions, and natural resource depletion.

The adoption of net foreign direct investment (FDI) inflow as an indicator for green finance stems from its positive and significant ability to attracts investment and investors from eco-friendly countries with stringent environmental regulations and high compliance standards. Alfaro and Rodríguez-Clare (2012) utilized this indicator and highlight its relevance in promoting green energy initiatives. The used of credit to the private sector as a proxy of green finance, emphasises the role of banks and financial institutions in funding green projects and initiatives. This credit facilitates innovation, research, and the development of environmentally friendly products and services, that mitigate risks associated with climate change and environmental degradation. Beck, Demirgüç-Kunt, and Levine (2004) adopted this proxy in their study and reported its importance in driving sustainable investments. Stock market capitalization measures green finance, as higher market capitalization for green companies attracts investor interest and confidence in environmentally responsible businesses. Aicheche and Nguyen (2021) observed that market performance of quoted green companies serves as a market signal for the financial viability and attractiveness of green investments. This holistic approach underscores the importance of integrating environmental considerations into financial decision-making processes to drive meaningful progress towards a greener future. The influence of environmental quality on green finance was controlled by using institutional quality, technology, education, and urbanization to examine the individual effect, which previous studies disregarded (Table 2).

Table 1

Sample SSA countries with GDP growth rate in 2023

SSA countries	GDP growth rate
Rwanda	6.2%
Côte d'Ivoire	6.2%
Benin	5.5%
Uganda	5.4%
Tanzania	5.2%
Kenya	5%
Togo	4.6%
Senegal	4.1%
Madagascar	4%
Algeria	3.8%

Source; Author (2024)

Table 2

Variables Description

Variables	Indicators	Measures	Source
Environmental Quality **(ENQ)**	Energy Usage **(EU)**	Per capita (kg of oil per capita)	Word Bank Indicators (2022)
	CO2 Emissions **(CO2)**	CO2 emissions per capita	
	Greenhouse Emissions **(ERM)**	Greenhouse emissions per capita	
	Natural Resource Depletion **(NRD)**	Natural Resource Depletion (% of GNI	
Financial Development (Green Finance)	Efficiency	Bank credit to the private sector, per cent of GDP **(BCP)**	
	Openness	Foreign Direct Investment (% of GDP) **(FDI)**	
	Market size	Stock market capitalization (% of GDP) **(STM)**	
	Controls		
Institutional Quality (Governance)	Government effectiveness index (-2.5 weak; 2.5 strong) **(GOV)**		
Technology	Mobile phone subscribers per 100 people **(TEC)**		
Urbanization	Urban population (% of total population) **(URP)**		
Education	Secondary school enrollment, per cent of all eligible children **(EDU)**		

Source; Author (2024)

Model Estimation Approach

Pre-Test

Cross-Sectional Dependency (CD) Tests

Prior to assessing the long-short-run nexus among the study variables, it is imperative to explore cross-sectional dependence, as the negligence of these tests, according to Shahbaz et al., (2018), will lead to spurious results. The CD test is expressed as

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{n-1} \sum_{i=1}^{n-1} (pij)\, N\,(0, 1) \quad \text{.....(Eq1)}$$

Where N and T = cross-sectional dimensions and period, respectively, and p_{ij} is the pairwise correlation of the errors.

Unit Root

The CADF and CIPS unit root models were adopted to examine the stationarity assets of the series. The equations are expressed as:

$$\Delta Y_{it} = \beta_1 + p_i Y_{it-1} + \beta_{iyit-1} + \sum_{j=0}^{k} Yij\Delta yit - 1 + \sum_{j=0}^{k} Yij\delta yit - 1 + \varepsilon_{it} \text{ ……..(Eq2)}$$

$$CIPS = \left(\frac{I}{N}\right) \sum_{j=1}^{k} ti\,(N, T) \text{…….(Eq3)}$$

where β_1 = deterministic term k lag order, and y_t = cross-sectional mean of time t.

Pooled Mean Group Autoregressive Distributed Lag Model (PMG-ARDL)

The PGM-ARDL was adopted for its ability to syndicate variables of diverse orders of integration (I(0) or I(1)) but not I(2), and control for endogeneity and serial autocorrelation, which previous studies ignored. The PMG-ARDL model is expressed linearly as

$ENQ = \beta_0 + \beta_1 BCP_{it} + \beta_2 FDI_{it} + \beta_3 STM_{it} + \beta_4 GOV_{it} + \beta_5 TEC_t + \beta_6 URP_{it} + \beta_7 EDU_{it} + \varepsilon_{it}$.....(Eq4)

Where ε_{it} = error term, i = cross-section, and t = period.

The PMG-ARDL model

$yit = \sum_{j=0}^{p} Yij\Delta yit + \sum_{j=0}^{p} \beta ijXi,t + \mu_i + \varepsilon_{it}$..... (Eq5)

$ENO_{it} = \psi_i + \sum_{j=0}^{p} \beta_{ij} BCP_{it-j} + \sum_{j=0}^{p} \chi_{ij} FDI_{it-j} + \sum_{j=0}^{p} \varphi_{ij} STM_{it-j} + \sum_{j=0}^{p} \Upsilon_{ij} GOV_{it-j} + \sum_{j=0}^{p} \vartheta_{ij} TEC_{it-j} + \sum_{j=0}^{p} \theta_{ij} URP_{t-j} + \sum_{j=0}^{p} \phi_{ij} EDU_{t-j} + \varepsilon_{it}$.....(Eq6)

Where $ENO_{it} = (EU_{it} + CO2_{it} + ERM_{it} + NRD_{it}$

t = period (t = 1,2,3 . . T)

i = country (i = 1,2,3. . . . N);

X_{it} (k x 1) = vector of explanatory variables for group i;

μ_i = fixed effect

(γ_{ij}) =coefficients of the lagged dependent variable

β_{ij} and k × 1 = coefficient vectors.

ε_{it} = error term.

The error correction model for the re-parameterized ARDL (p, q, q . . . q) can be specified as

$\Delta y_{it} = \theta_i[y_{it-1} - \lambda_i X_{it}] + \sum_{j=0}^{p-1} \gamma_{ij} \Delta y_{it-j} + \sum_{j=0}^{q-1} \beta_{ij} \Delta y_{it-j} + \mu_i + \varepsilon_{it}$..... (Eq7)

Hausman Test

The Hausman test was performed to determine the most appropriate estimator under the null hypothesis of homogeneity between:

Pooled Mean Group (PMG); ii. Mean Group (MG), and iii. Dynamic fixed effects (DFE).

The PMG is preferred when either the N or T values are small. The PMG pooled the MG estimators' features, such as averaging the individual equations for each cross-section, to produce consistent estimators.

Results

Table 3

The Descriptive Statistics

	EU	CO2	ERM	NRD	BCP	FDI	EDU	STM	GOV	TEC	URP
Mean	592.5255	0.566484	45630.50	5.390830	15.95063	-67305313	41.61987	29.81448	-0.643564	47.77435	8862079.
Median	434.8388	0.269675	24690.72	3.783930	13.25132	1.386471	39.21269	26.50727	-0.585880	45.95331	6993189.
Maximum	3912.261	3.994402	279200.6	24.64426	36.64775	13.84758	99.61435	80.54854	0.308449	162.1701	33575039
Minimum	54.73064	0.052654	3117.582	0.000283	3.112803	-1.27E+09	9.953290	0.000000	-1.534019	0.079282	1126468.
Std. Dev.	712.1401	0.929708	61720.20	5.499786	7.570022	2.32E+08	18.09238	29.29372	0.365703	39.65517	7074121.
Skewness	3.213731	2.662504	2.395848	1.317190	0.699779	-3.578365	0.726616	0.441452	-0.325568	0.386809	1.487646
Kurtosis	13.97430	8.706615	7.967385	4.338859	2.510225	14.81896	3.491607	1.565240	3.040190	2.121425	4.864629
Jarque-Bera	1603.995	558.4441	440.6261	80.04790	21.80321	1845.430	14.21943	24.71476	3.723931	13.13280	123.2920
Probability	0.000000	0.000000	0.000000	0.000000	0.000018	0.000000	0.000817	0.000004	0.155367	0.001407	0.000000

Source; Author (2024)

The descriptive statistics results in Table 3 for the study "Green Finance and Sustainable Development in SSA countries show that, the 10 selected SSA countries considered as fast-growing and stable after the COVID-19 pandemic use 592.53 kg of energy, emits 0.57 kilotons of CO2, releases 45630.50 kilotons of other greenhouse gases per capita, and deplete natural resources by 5.39% per annum. The high standard deviation of 712.14 indicates a wide dispersion in energy consumption levels and energy efficiency in SSA countries. The high average and median values of (15.95 and 13.25) indicate a generally positive trend in bank credit availability for private sector activities, and the standard deviation reflects the disparity in SSA countries' access to credit. The negative average value of net foreign direct investment and the high standard deviation indicate significant variability among SSA countries. The average and median values indicate variations in stock market capitalization, reflecting the differences in financial market development across the selected SSA countries.

The average and median values of government effectiveness in measuring institutional quality in the selected SSA countries promote sustainable development. A positive skewness indicates an inclination towards robust government effectiveness. The high standard deviation of 39.66 mobile phone subscribers per 100 people measuring technological development indicates significant variability in infrastructure development. The high standard deviation of 29.29 suggests diverse levels of urbanization, possibly reflecting differences in economic structure and development.

The results in Table 3 highlight the diversity among SSA countries in terms of energy usage, environmental impact, financial indicators, and institutional and technological factors. The utilization of PMG-ARDL provides a more robust assessment and policy inferences for stimulating sustainable development in the region, with a focus on the role of financial development and institutional quality.

Cross-Sectional Dependence

The CD results in Table 4 show cross-sectional dependency among SSA countries, as such countries are not entirely independent from each other. Shocks experienced from global epidemics, financial crises, technological progress, and cross-border pollution can quickly spread across regions, economic bloc and nations.

Table 4

Cross-Sectional Dependence Test Results

	Test-Statistic
Breusch-Pagan LM	103.604***
Pesaran scaled LM	20.712***
Bias-corrected scaled LM	13.309***
Pesaran CD	6.9018**

Source: Author (2024). ***** significance level of 5%

Table 5

Second Generational Unit Root Test Results

	Constant and Trend			
	CIPS		**CADF**	
Variables	Levels	Ist Difference	Levels	Ist Difference
EU	-3.981***	-6.012***	-0.081	-6.012***
CO2	-3.001***	-5.031***	-1.812	-5.031***
ERM	-2.891***	-6.012***	-2.061***	-6.012***
NRD	-3.080***	-4.925***	-0.021	-4.925***
BCP	-4.012***	-4.512***	-5.901***	-3.700***
FDI	-3.011***	-4.069***	-5.151**	-3.812***
EDU	-3.381***	-4.001***	-4.671***	-4.810***
STM	-4.012***	-4.512***	-3.991***	-5.151**
GOV	-4.802***	-6.126***	-3.671***	-4.671***
TEC	-5.102***	-7.923***	-3.881**	-5.405***
URP	-3.612***	-5.871***	-2.051**	-5.812***

****Critical values of CIPS = 1% -2.250, -3.510, -2.130:
CADF= 1% -2.012, -1.958, -2.001.

Source: Author's (2024).

Before estimating the long-short-run nexus, determining the stationarity assets of the series is key to the dependability of the PMG-ARDL results. The unit root results in Table 5 reveals diverse orders of integration. Thus, providing credibility to adoption of the PMG/ARDL estimator.

The PMG/ARDL model was adopted as a more efficient model than the mean group (GM) results, and the long-run nexus is presented in Table 6.

Table 6
Results of long-run PMG-ARDL Estimation

Panel A: Long Run Equation				
Variable	**EU**	**CO2**	**ERM**	**NRD**
Models	**(2,0,0,10,1)**	**(1,1,1,1,1,1,1)**	**(2,2,2,1,2,2,2)**	**(2,1,1,1,0,1,0,0)**
BCP	0.8523	0.891	-0.363	0.860
	(8.6072)**	(5.6600)**	(-5.663)**	(11.061)**
FDI	0.91143	-0.70115	-0.196	0.4735
	(12.3475)**	(-14.9014)**	(-4.543)**	(10.769)**
STM	0.9601	0.5595	-0.697	0.399
	(10.1716)**	(7.5924)**	(-6.611)**	(9.628)**
EDU	0.8114	0.097	0.307	0.546
	(10.992)**	(3.294)**	(4.784)**	(1.782)**
GOV	0.8198	-0.3053	0.196	0.5882
	(7.9182)**	(-12.9166)**	(4.5433)**	(9.2557)**
TEC	0.9119	0.8590	10.491	14.681
	(9.9049) **	(9.8158)**	(9.435)**	(7.1001)**
UPR	0.940	0.950	14.681	0.7552
	(6.262)**	(5.289)**	(7.1001)**	(11.666)**
Panel B: Short-Run Equation				
CointEq(-1)*	-0.8978	-0.5452	-0.8378	-0.7545
	(-13.231)**	(-7.8406)**	(-8.7798)**	(-16.309)**
Hausam Test Results	5.8700 (0.3981)	6.901 (0.6891)	4.890 (0.5470)	8.920 (0.3012)

Source: Author (2024). ** significance level of 5%

Discussion

Greenhouse Emissions

The negative results imply that a 1% decrease in bank credit to the private sector may lead to the relocation of MNCs to countries with lax environmental regulations (pollution haven). Thus, increasing greenhouse gas emissions in industries may prioritize cost savings over environmental responsibility. The net inflow of FDI from countries with stringent and high environmental compliance costs to countries with lax environmental standards to reduce operational costs increases greenhouse gas emissions in the host country. In pursuit of short-term profits, companies listed on the stock market may prioritize cost-cutting measures to decrease environmental quality and increase emissions. Institutional quality, technology, and urbanization positively reduce greenhouse gas emissions through the investment and development of renewable energy. Urbanization supports energy-efficient infrastructure, public transportation, and waste management, thereby reducing per capita emissions. The findings of Khan, Polat and Bashir (2023); Udo, et al., (2023); Udo, et al., (2019), Enoch, et al., (2023), Abner et al., (2023), Udo, et al., (2024) support the study findings of regulatory environments, financial constraints, and urban development in influencing greenhouse gas emissions.

Natural Resource Depletion

The diminution of natural resources is a significant environmental concern, and various economic and social factors have influenced the rate of depletion over the years. From the long-run results, a unit increase in bank credit promotes natural resource conservation and biodiversity preservation through investment in sustainable practices and technologies, leading to an 86% more efficient use of natural resources. The net inflow of FDI promotes investment in industries that prioritize sustainable practices, mitigating the negative impacts on natural resources by 47%. Companies with high market capitalization attract investments by 39% based on their commitment to sustainability and environmentally conscious practices. Robust institutional quality enforces and regulates environmental laws, prevents the overexploitation of natural resources, and leads to the development of eco-friendly technologies and processes, promoting sustainable resource management by 58%. Urbanization leads to 75 % more efficient resource usage, waste management, and sustainable consumption patterns. A high education level increases awareness of the environmental consequences of resource depletion, fostering conscious consumption. Green finance initiatives are crucial for directing investments towards sustainable projects and contributing to economic and ecosystem stability in the region.

CO2 Emission

Green finance proxied by bank credit to the private sector (efficiency) and stock market capitalization (market size) positively and significantly influences sustainable development. This implied that a 1% increase in

bank credit to the private sector increases investments in cleaner technologies and sustainable practices, thus reducing the carbon intensity of industries. A 1% increase in stock market capitalization attracts investment in green and sustainable industries, promoting environmentally friendly practices. Findings revealed that higher educational levels lead to increased awareness of environmental issues and sustainable practices, which influences consumer behaviour and corporate responsibility and encourages reduction in fossil energy consumption to improve environmental quality. Urbanization increases the energy demand, which increases CO2 emissions.

Similarly, urbanization can lead to a more efficient use of resources and energy because of the adaptation of cleaner technologies and sustainable urban planning through advanced technologies that reduce overall carbon emissions. Poor institutional quality, characterized by weak governance and corruption, hinders the effective implementation and enforcement of environmental regulations. Lack of regulatory oversight may lead to environmentally harmful practices by industries, contributing to higher CO2 emissions. As such, most MNCs prioritize economic gain over environmental sustainability.

Energy Usage

The positive and significant influence of green finance proxied by bank credit to the private sector (efficiency), foreign direct investment (openness), and stock market capitalization (market size) on sustainable development proxied by energy usage revealed that an increase in bank credit to the private sector facilitated investments in energy infrastructure and promoted the adoption of energy-efficient technologies and green energy development projects. An increase in net FDI inflow attracts capital and green technology nations with sustainable green energy projects to reduce CO2 emissions and foster innovation in the energy sector through energy companies listed on the stock market with access to capital for investment and research in renewable infrastructure. Educational level, technology, institutional quality, and urbanization positively enhances the embrace of energy-efficient technologies and practices in cities through transparent and effective institutions. Fossil fuel consumption increases with population growth and urbanization. Balancing economic growth with sustainable practices is essential, especially in the context of the vulnerability of African countries to climate change.

Error Correction Model (ECM) Results

From the short-run estimate in Panel B, the ECM values of CointEq(-1) of (-0.8978) for energy usage, (-0.5452) for CO2 emissions, (-0.8378) greenhouse emissions, and (-0.7545) for natural resource depletion are correctly signed, which is negative and statistically significant, confirming the existence of a long-run speed of convergence from short divergence caused by economic pressures, lax regulatory frameworks, conflicts and instability, technological constraints, climate change impacts, and global market dynamics, among others, in SSA countries.

Findings reveals a multifaceted influence and implications of institutional quality, technology, and urban population on sustainable development, particularly through environmental quality in SSA, which is greatly affected by climate change. To circumvent the pollution havens effect, African countries must prioritize sustainable development, invest in green technologies, and strengthen institutional frameworks to ensure effective environmental governance. Balancing economic growth with environmental stewardship is crucial, especially since seven of the ten countries most vulnerable to climate change impacts in Africa. The findings of Udo, et al., (2024), Ji et al., (2021), Abner et al., (2023), Enoch et al., (2023), Udo et al., (2023), Ntow-Gyamfi et al., (2020) are consistent with the findings of this study.

Conclusion

In conclusion, this study assesses and provides appreciated insights into the intricate nexus between green finance and sustainable development in 10 selected sub-Saharan Africa (SSA) countries considered in 2023 by the World Bank as fast growth and stable after the COVID-19 pandemic. The investigation focused on key environmental indicators of natural resource depletion, greenhouse gas emissions, CO2 emissions, and energy usage, shedding light on the complex interplay of economic, social, and environmental factors. The results indicate that green finance, proxied by bank credit to the private sector, plays a pivotal role in promoting sustainable practices. An increase in bank credit to the private sector increases investments in industries that prioritize sustainability, conservation, and biodiversity preservation.

Similarly, the negative relationship between green gas emissions and net FDI inflow reveals potential adverse consequences associated with the risk of increased greenhouse gas emissions due to the relocation of multinational corporations (MNCs) to SSA countries due to lax environmental regulations associated with weak

regulatory frameworks. Educational development proxied by secondary school enrollment significantly improves environmental quality through awareness of the impact of climate change. In the long run, SSA countries investing in post-primary education will benefit from sustainable environmental quality.

The comprehensive findings of this study provide a foundation for holistic and informed decision-making. This study, among other things, recommends the formulation and implementation of strategic green finance policies to align investments with development goals, enhanced regulatory oversight to improve environmental quality by reducing harmful practices in industries. SSA countries must balance economic growth and environmental stewardship through sustainable development strategies to avoid long-term environmental degradation, given their countries' vulnerability to climate change.

This study provides empirical evidence on the multifaceted influence of institutional quality, technology, and urbanization on sustainable development in SSA and fills the knowledge gap. These findings underscore the importance of addressing environmental challenges in tandem with economic development.

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