

Original Research

**Stock Market Development and CO<sub>2</sub> Emissions in Africa: The Moderating Role of Domestic Credit to the Private Sector**

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**Received:** January 06, 2026**Accepted:** May 27, 2026**Published:** June 04, 2026**Abstract**

This study examines the effects of stock market development (SMC) and renewable energy consumption on CO<sub>2</sub> emissions in nine African economies over the period 2000-2024. It also tests whether domestic credit to the private sector (DC) moderates the relationship between stock market development and CO<sub>2</sub> emissions. Panel data econometrics, including Feasible Generalized Least Squares (FGLS) for the main estimates and Panel-Corrected Standard Errors (PCSE) for robustness checks, are used as the primary analytic technique in this study. The results of this study suggest that a one percent increase in SMC results in about a 0.09-0.14 percent increase in CO<sub>2</sub> emissions; conversely, DC contributes an additional amount of CO<sub>2</sub> emissions of about 0.20-0.34 percent. On the other hand, a one percent increase in renewable energy consumption reduces CO<sub>2</sub> emissions by about 0.44 to 0.54 percent. The research also found a statistically significant positive interaction term, indicating that greater credit market depth contributes to higher-carbon outputs driven by stock market activity. To support the sustainable economy, African governments should incentivize the development of “green finance” instruments such as green bonds, sustainability-linked equity instruments, and require that investors include climate risk assessments in their lending portfolios. In addition, governments should require that publicly traded corporations disclose information related to



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their climate-related vulnerabilities and should provide market-wide incentives such as carbon pricing, tax credits for companies that implement green initiatives, and subsidized lending to companies that invest in low-carbon initiatives. Overall, the findings of this study indicate that the financial sector is and will continue to influence the ability of African economies to effectively transition to and utilize renewable energy sources, while also impacting the formulation of their energy policies and how they will achieve their respective decarbonization strategies.

### **Keywords**

Renewable energy consumption; CO<sub>2</sub> emissions; green finance; domestic credit; stock market development

## **1. Introduction**

The relationship between CO<sub>2</sub> emissions, stock-market development, and domestic credit to the private sector in Africa is a vital research issue, due to the potential for co-occurrence of fast economic growth and high environmental stress (via CO<sub>2</sub> emissions). The links between environmental sustainability (ES) and the financial system are in their infancy, offering a valuable opportunity to combine socio-economic performance with financial support and improved CO<sub>2</sub> outcomes, i.e., by increasing financing of projects that reduce carbon emissions while simultaneously improving ES. This introductory review aims to outline the different components of this relationship and to accentuate the need to promote the development of sustainable finance mechanisms that will support an increase in overall socio-economic performance and, in turn, raise the level of overall ES.

Through stock market development, Africa has an opportunity to access external capital and to aid in creating economic growth. Financial markets have a potential role in providing capital for sustainable development via facilitating the funding of environmentally sustainable initiatives (via investment in green finance). Research shows that green financing systems enable businesses to connect their financial outcomes to social and environmental results, bridging financial systems with sustainable operations [1]. The recent increase of Environmental Social and Governance (ESG) benchmarks further supports the integration of sustainability in the decision-making process of investing in businesses, as companies can now demonstrate improved financial performance as a direct result of their implementation of sustainable business practices [2]. African economies have established several stock markets as part of their efforts to encourage sustainable economic growth by applying various forms of financial tools. The relationship between the growth of financial systems and the growth of domestic credit provided to the private sector and emissions, however, differs across different types of economies. Research shows that financial development creates economic growth opportunities, but it can harm the environment unless proper regulatory measures are in place [3].

The Environmental Kuznets Curve (EKC) hypothesis posits that economic growth initially harms the environment but eventually improves environmental quality as income increases [4, 5]. Studies on the EKC in the context of African economies have produced conflicting findings, prompting

researchers to conduct additional work examining various aspects of African economic growth in greater detail [6].

In this study, GDP per capita is used to capture the economic-growth aspect of the Environmental Kuznets Curve (EKC) framework. It is included as a control variable in the empirical model. Testing the EKC framework is not the main focus of the study; rather, it provides a theoretical basis for accounting for the economic growth and CO<sub>2</sub> emissions link while examining the roles of stock market development, renewable energy consumption, and domestic credit.

The exploration of the relationship between stock market development and CO<sub>2</sub> emissions requires researchers to examine how domestic credit to the private sector affects both systems. The availability of credit affects how companies finance their investments in cleaner technologies and, in turn, their overall greenhouse gas emissions. As domestic credit expands, purchasing cleaner technologies becomes increasingly easier, which has a direct impact on the reduction of CO<sub>2</sub> emissions. The complex relationship between energy policies, economic growth, and environmental strategies requires policymakers to develop sophisticated methods [3]. These policies must balance the broader impact of economic financialization, including credit availability and stock market conditions, with the urgent need to assess and address long-term environmental implications.

Therefore, this study investigates the effects of stock market development and renewable energy consumption on CO<sub>2</sub> emissions in nine African economies over the period 2000-2024. Additionally, this study examines whether the level of domestic credit to the private sector moderates the association. The study uses panel data methods, specifically Feasible Generalized Least Squares (FGLS) and Panel-Corrected Standard Errors (PCSE), to contribute to the literature by identifying the relationship among stock market development, domestic credit, and CO<sub>2</sub> emissions, with renewable energy consumption acting as a means of mitigating emissions in Africa. The results of this study provide evidence for policymakers and can help them align capital market development, credit allocation, and green finance with the objective of long-term sustainable development.

## **2. Literature Review**

### **2.1 Theoretical Framework**

This study applies an integrated theoretical framework grounded in environmental economics, financial development, and sustainability theory to analyze how stock market development and renewable energy consumption affect CO<sub>2</sub> emissions in nine African countries and assess whether domestic credit to the private sector moderates the association. The Environmental Kuznets Curve (EKC) is central to this framework, proposing that pollution typically rises during the initial stages of growth as production and energy use intensify, but can fall once higher income levels make cleaner technologies and tougher environmental regulation more feasible [7]. Therefore, in Africa, stock market development should lead to an increase in CO<sub>2</sub> emissions because the increased amount of capital available through SMC is backed by financial institutions that are providing loans for financing polluting industries. It may also create an opportunity to provide green finance as stock market development approaches and exceeds the EKC peak [8].

This perspective aligns with the Sustainable Development Goals, which emphasize pursuing economic progress alongside environmental protection, particularly through SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) [9]. Renewable energy would be an effective positive pathway to disassociate growth from emissions, with evidence demonstrating that countries'

markets that attract investment in solar, wind, and other clean tech can lower carbon emissions during economic growth [10, 11]. However, the shift to a green economy cannot be achieved without adequate financing; without it, participation from the financing sector will be limited, sporadic, and prone to reverting to fossil fuel reliance, as financing borrowers and the underlying economics of distribution lock low-income populations into higher-carbon-emission energy sources.

Domestic credit to the private sector is a key moderating factor in this study. According to [12, 13], reduced financing expenditures and increased capital availability through domestic credit provision lead to lower funding levels, thus mitigating the environmental pressures that can accompany rapid market expansion. [14], in their study, they focus on credit markets within carbon-intensive business operations, which lead to increased environmental pollution. They demonstrate how the expansion of financial markets creates negative effects when lenders lack green lending standards.

Financial inclusion will also shape this expected outcome by democratizing access to financial services. Financial inclusion will provide both increased liquidity to a market and greater opportunity for lower-income households and small businesses to invest in clean energy products like distributed solar that will provide spillover benefits to the environment [15, 16]. Conversely, if the priority of increased inclusion is to maximize volume rather than sustainability, the intention of providing even minimal subsidies towards sustainable outcomes, new banked consumers may increase their consumption of fossil-fuel-based goods and temporarily raise emissions while waiting for the longer-term effects of inclusive green finance to establish themselves, then this may occur.

Finally, corporate governance and corporate social responsibility (CSR) frameworks help contextualize these relationships. It is often observed that firms that disclose performance and engage in CSR activities enjoy lower capital costs and higher investor confidence. Firms that disclose performance and firms that engage in CSR activities encourage green investment [17-19]. When disclosure standards and CSR practices are weak, market actors may overlook environmental externalities, even as financial markets expand.

In summary, this integrated framework highlights both positive and negative dynamics: stock market growth and financial development can increase CO<sub>2</sub> emissions, but they can move towards sustainable trajectories if combined with targeted domestic credit, investments in renewable energy, financial inclusion, and effective environmental regulation. Policymakers in African states must therefore align financial regulations, credit policies, and market oversight with sustainability objectives to fully harness the potential of capital markets to improve the environment.

This study focuses on three hypotheses:

- (H1): A positive relationship exists between the stock market development (SMC) and the CO<sub>2</sub> emissions.
- (H2): There exists a negative relationship between the usage of renewable energy (REN) and the resulting CO<sub>2</sub> emissions that occur as a result of that consumption (usage) of renewable energy in general.
- (H3): The moderating effect of domestic credit to the private sector (DC) on the stock market-emissions link.

## **2.2 Stock Market Development and CO<sub>2</sub> Emissions**

The stock market in Africa is in many ways a significant factor in CO<sub>2</sub> emissions, both positively through greater investment in green technology, and negatively through the lack of stringent regulations resulting in environmental abuse. On the plus side, developed financial markets can create pathways for increased capital flow toward renewable energy and low-carbon projects through tools such as green bonds and sustainability-linked securities, thus decreasing the carbon intensity of investment portfolios [13, 20]. Stock exchanges can further enable companies to access R&D funding for clean-technology innovations that will allow them to implement sustainable production processes, and ultimately reduce their emissions [14, 21]. Additionally, combining stock market financing and green financing strategies helps align investors' interests with sustainable goals over the long term. It creates a framework in which sustainable businesses can thrive [22, 23].

On the other hand, the increase in CO<sub>2</sub> emissions may result from an emphasis on economic growth over environmental sustainability, driven by a desire for and need for financial growth, rather than placing equal emphasis on environmental sustainability [24-26]. This pattern is often framed through the Environmental Kuznets Curve, which posits that emissions tend to rise as economies grow up to a particular income threshold, after which environmental conditions may improve [27]. In sub-Saharan Africa, where many stock markets are still developing, the environmental effects of stock-market development may be shaped by institutional quality and governance. Inadequate frameworks for allocating funds can divert structural capital to carbon-heavy industries and adversely affect climate-related objectives [28, 29]. Hence, while the African stock markets offer great potential for financing sustainable development, the environmental upside still depends on sound regulation and some focus on environmental risk and green finance.

## **2.3 Renewable Energy Consumption and CO<sub>2</sub> Emissions**

The link between renewable energy use and CO<sub>2</sub> emissions is increasingly important in Africa, given rising energy demand, ongoing socio-economic change, and mounting environmental pressures. The dependence on fossil fuels in Sub-Saharan Africa, which contributes to rising CO<sub>2</sub> emissions, acts as an impediment to climate change goals. Accordingly, integrating renewable energy technologies into national energy strategies in Sub-Saharan Africa is essential for advancing sustainable development [30]. Previous studies have shown a connection between increased renewable energy use and decreased CO<sub>2</sub> emissions. [31] use panel cointegration techniques to show this link in six North African countries. They find that emissions decrease as renewable energy use increases. [32] extend the Environmental Kuznets Curve (EKC) model to Sub-Saharan Africa, examining differences in renewable energy uptake across the economies, and find that increases in renewable energy are associated with levels of economic growth, causing emissions to fall.

However, using renewable energy to reduce carbon emissions is not guaranteed to have this effect. The development of financial systems in a country can act as a key moderator of how renewable energy use translates into lower CO<sub>2</sub> emissions. [33] contend that, in the absence of strong financial systems, the influx of capital through green technology investments will fall short of its true potential to reap the rewards of these new technologies, limiting their positive impact on the environment. [11] Low levels of financial inclusion are preventing access to capital by renewable projects in Sub-Saharan African economies. Similarly, [34] emphasizes the need for domestic credit to promote financial development for renewable energy projects. [20] highlight that the country's

institutional financial structure variable in Ghana increased the benefits of using renewables and producing lower overall emissions.

Beyond finance, governance and policy frameworks, which play a pivotal role, good governance, effective environmental policies, and dedicated incentives are instrumental in facilitating the uptake of cleaner practices and low-carbon technologies [35, 36]. The studies conducted by [37, 38] highlighted the important role of effective governance and access to environmentally friendly technology on greenhouse gas emissions through energy consumption. [39] identified several obstacles to the development of renewable energy systems, including difficulty in securing funding and challenges with implementing policies related to renewable energy technologies. There is a clear need to converge solutions across a range of levels as existing renewable energy capacity increases, integrating clean technology, financial development, and institutional reform.

In sum, the increase of renewable energy will result in increased reductions in CO<sub>2</sub> emissions while contributing to sustainable development in Africa's economy. The extent to which renewable energy can contribute to sustainable development in Africa will depend on the existence of functioning financial systems that are functioning effectively: financial inclusion, the inclusion of private companies, and governance. Because of this, the creation of clean energy systems must consider all of the above as elements that will enhance coordination among the financial systems of both public and private energy markets and the public policy frameworks that have the power to reduce CO<sub>2</sub> emissions within African economies.

#### ***2.4 Domestic Credit as a Moderator***

By promoting clean investments and enabling high-carbon growth, stock market development influences CO<sub>2</sub> emissions. Domestic credit plays a significant role in these dynamics. The expansion of stock markets allows them to mobilize and allocate funds to renewable energy projects and other low-carbon activities through instruments such as green bonds and sustainability-linked securities, thereby contributing to emissions reductions [13, 40]. A more developed capital market can also provide firms with capital for research & development to adopt clean technologies and other eco-innovations that lower CO<sub>2</sub> emissions [14, 21]. However, without strong environmental regulations, growth of financial activity may spur industrial activity in polluting industries with emissions increasing in line with the Environmental Kuznets Curve until reaching that GDP threshold [24, 41].

Domestic credit to the private sector modulates these pathways: well-allocated credit can reinforce the green-finance channel, enhancing firms' capacity to invest in sustainable ventures, while credit growth directed toward traditional industries may magnify carbon-intensive output [25]. In sub-Saharan Africa, where capital markets and credit markets are comparatively new in development, institutional quality and governance are important to determining outcomes; whether stock market and credit growth contribute to environmental sustainability or preventively lock economies in high emission pathways [42]. Overall, it is important to get stock market development and domestic credit that underpins it in step with regulations to harness positive green investment pathways and simultaneously manage negative emissions pathways.

### 3. Methodology and Data

#### 3.1 Model and Data

This research aims to explore the effects of stock market development and renewable energy on CO<sub>2</sub> emissions in Africa, including the moderating effect of domestic credit across nine African countries with stock markets, using the available data on the core variables required for the empirical analysis.

The study’s empirical model draws on earlier studies, with key guidance taken from [43, 44].

$$\ln CO_{2,it} = f(SMC_{it}, REN_{it}, X_{it}, \varepsilon_{it}) \tag{1}$$

Where  $\ln CO_{2,it}$  is carbon emission,  $SMC_{it}$  is stock market development,  $REN_{it}$  is renewable energy,  $X_{it}$  is a set of control variables (economic growth, industrialization, education, and trade openness).

All variables are converted to natural logarithms for more precise estimation [45]. The baseline empirical specification is expressed as:

$$\begin{aligned} \ln CO_{2,it} = & \alpha + \beta_1 \ln SMC_{it} + \beta_2 \ln REN_{it} + \beta_3 \ln EG_{it} + \beta_4 \ln IND_{it} \\ & + \beta_5 \ln EDU_{it} + \beta_6 \ln TO_{it} + \theta_i + \delta_t + \varepsilon_{it} \end{aligned} \tag{2}$$

With  $i$  and  $t$  representing country and year, respectively,  $\ln CO_{2,it}$  is used to denote carbon emission. The two core explanatory variables are  $\ln SMC_{it}$ , which is stock market development, and  $\ln REN_{it}$ , which is renewable energy.  $\ln EG_{it}$ ,  $\ln IND_{it}$ ,  $\ln EDU_{it}$ , and  $\ln TO_{it}$  are used as control variables.  $\theta_i$  captures country-fixed effects,  $\delta_t$  captures time-fixed effects, and  $\varepsilon_{it}$  denotes an unobserved error term.

The study will further check the moderating effect of domestic credit (DC) on carbon emission. To examine moderation, the model is expanded to include an interaction term as follows:

$$\begin{aligned} \ln CO_{2,it} = & \alpha + \beta_1 \ln SMC_{it} + \beta_2 \ln REN_{it} + \beta_3 \ln EG_{it} + \beta_4 \ln IND_{it} \\ & + \beta_5 \ln EDU_{it} + \beta_6 \ln TO_{it} + \theta_i + \beta_7(SMC_{it} * DC_{it}) + \delta_t + \varepsilon_{it} \end{aligned} \tag{3}$$

The study employs panel data for nine African countries (Table 1) over the period 2000-2024 and uses eight variables, as defined in Table 2.

**Table 1** Selected countries for the study.

1	Botswana	6	Morocco
2	Egypt, Arab Rep.	7	Nigeria
3	Ghana	8	South Africa
4	Kenya	9	Tunisia
5	Mauritius		

**Table 2** Variable Description.

	Variable	Abbreviations	Description	Data Source
Dependent variable	Carbon emission	CO <sub>2</sub>	Total carbon dioxide emissions excluding LULUCF, reported in MtCO <sub>2</sub> e (and/or as an index relative to the 1990 baseline, depending on the series used)	WDI
Independent Variable	Stock market development	SMC	Market capitalization of listed domestic firms as a share of GDP (%)	WDI
	Renewable energy	REN	Renewable energy consumption as a share of total final energy consumption (%)	WDI
Control Variables	Economic growth	EG	GDP per capita in constant 2015 US dollars	WDI
	Industrialization	IND	Industry (including construction) value added, measured in current US dollars.	WDI
	Trade openness	TO	Total trade (exports + imports) as a percentage of GDP (%)	WDI
	Education	EDU	School enrollment, secondary (% gross)	WDI
Moderating variables	Domestic credit	DC	Domestic credit to the private sector provided by the financial sector as a percentage of GDP (%)	WDI

### 3.2 Estimation Strategy

Before estimation, the study applies Pesaran [46] cross-sectional dependence test to assess whether shocks are correlated across countries and to guide the choice of appropriate panel estimation methods.

$$S = \sqrt{\frac{2L}{M(M-1)}} \sum_{i=1}^{M-1} \sum_{j=i+1}^M r_{ij} \tag{4}$$

Where  $M$  is the number of countries,  $L$  is the number of time periods, and  $r_{ij}$  denotes the sample correlation between the residuals of countries  $i$  and  $j$ .

At conventional significance levels, if we reject the null hypothesis  $H_0: r_{ij} = 0 \forall i \neq j$ , we have identified cross-sectional dependence and should proceed to use second-generation panel techniques.

After the cross-sectional dependence test, the study proceeds with stationarity to retain regression results that are valid, reliable, and meaningful, to avoid spurious correlations, and establish correct model specification. If cross-sectional dependence is confirmed, the study employs second-generation panel unit-root tests to assess stationarity and minimize the likelihood of spurious regression outcomes [47]. The study used the Breitung test for testing the variables for stationarity because it yields a lambda statistic robust to possible cross-sectional dependence, making it a necessary approach in the case of CSD.

To address potential cross-sectional dependence (CSD), the study applies both first- and second-generation panel unit-root tests:

- First-generation: As an initial benchmark, it uses the Breitung test, which assumes cross-sectional independence.
- Second-generation: Pesaran [48] CIPS test captures individual ADF regressions enhanced by cross-sectional averages:

$$\Delta_{it-1} = \alpha_i + b_i \cdot x_{it-1} + c_i \bar{x}_{t-1} + d_i \Delta \bar{x}_t + u_{it} \tag{5}$$

$$\bar{x}_{t-1} = \frac{1}{M} \sum_{k=1}^M x_{k,t-1}$$

$$\Delta \bar{x}_t = \frac{1}{M} \sum_{k=1}^M \Delta x_{k,t}$$

The individual t-statistic from (2), denoted  $S_i(L, M)$ , is averaged to form the GIPS statistic:

$$GIPS = \frac{1}{M} \sum_{i=1}^M S_i(L, M) \tag{6}$$

Rejection of stationarity for the series implies they are integrated of order one.

Given non-stationarity and significant CSD, the study employs Westerlund [49] second-generation panel cointegration tests to test long-run equilibrium relationships that are valid in the presence of CSD. If we reject the null of no cointegration, this confirms that we are estimating a stable long committee.

After the pre-estimation tests, the study employed the feasible generalized least squares (FGLS) methodology of [47, 50]. The Parks-Kmenta FGLS approach is well-suited to panels that exhibit individual effects, heteroskedasticity, serial correlation, and cross-sectional dependence [47, 50, 51], as is characteristic of the dataset in the study. The study also employed the panel-corrected standard error (PCSE) technique of [52] as a robustness test, as it is an alternative method for handling short and wide panels, which the study is conducting. The PCSE approach retains the OLS point estimates. Still, it adjusts the standard errors to better reflect heteroskedasticity and contemporaneous correlation, helping to mitigate the tendency of FGLS to understate standard errors in finite samples [52].

#### 4. Empirical Results and Discussion

##### 4.1 Econometric Methodology

Table 3 displays the summary statistics of the dataset, providing information on how the data is distributed and varies across various metrics. The mean values offer insights into the average values of indicators like CO<sub>2</sub> emissions at around 3.4974, while stock market development and renewable energy used averaged 3.4382 and 3.0708, respectively. On the other hand, the standard deviation values indicate variations within the dataset with variables showing a notably lower dispersion around their mean, pointing to small disparities among the observations. To directly compare the variables measured on multiple scales, we have also calculated the Coefficient of Variation (CV = SD/Mean); these results again indicate that CO<sub>2</sub> has relatively greater variability than EG and IND, with a CV of 0.4516 versus 0.0751 and 0.0589, respectively. The minimum and maximum stats highlight the data's range. Moreover, all the variable correlation coefficients are less than 0.75; in which 0.8 as the threshold used in the literature; This indicates that the model is unlikely to suffer from serious multicollinearity among the explanatory variables [53]. The variance inflation factors reported in Table 4 provide additional reassurance: the maximum VIF is 3.85, and the mean VIF is 3.26, both well below the commonly cited threshold of 10, indicating that multicollinearity is not a major concern in the estimated models.

**Table 3** Summary statistics.

STATS	CO <sub>2</sub>	SMC	REN	EG	IND	EDU	TO
Mean	3.4974	3.4382	3.0708	8.0934	23.4823	4.2243	4.1189
SD	1.5796	1.1071	0.9197	0.6078	1.3833	0.3281	0.5232
Min	0.8931	0.9153	1.5268	6.9298	20.9056	3.2088	1.9343
Max	6.1901	5.7768	4.4785	9.3612	25.7984	4.9089	4.8525
CV	0.4516	0.3220	0.2995	0.0751	0.0589	0.0777	0.1270
N	225	163	225	225	225	225	225
CO <sub>2</sub>	1						
SMC	0.3152*	1					
REN	-0.3411*	-0.5708*	1				
EG	-0.0721	0.6394*	-0.6371*	1			
IND	0.9319*	0.1563*	-0.2000*	-0.0984	1		
EDU	0.0728	0.5983*	-0.7365*	0.7066*	0.0384	1	
TO	-0.5678*	0.2383*	-0.3427*	0.4450*	-0.6199*	0.5069*	1

Note: \* shows the coefficients are significant at the 5% level of significance.

**Table 4** Variance Inflationary Factor.

Variable	VIF	1/VIF
EG	3.85	0.2594
TO	3.73	0.2677
REN	3.68	0.2717
SMC	3.39	0.2950
IND	3.01	0.3323
EDU	1.91	0.5227
Mean VIF	3.26	

#### 4.2 Cross-Sectional Dependence, Panel Unit-Root, and Cointegration Tests

As shown in Table 5, the Pesaran [46] CD test indicates significant cross-sectional dependence ( $p < 0.01$ ). Unit-root results from Breitung and Pesaran [48] CIPS imply that the variables become stationary after first differencing, and the Westerlund [49] panel tests support a long-run relationship.

**Table 5** Diagnostic Tests: Cross-Sectional Dependence and Panel Unit Roots.

Variables	Pesaran CD	Breitung		Pesaran CIPS	
		Level	1st Diff	Level	1st Diff
<i>lnCO<sub>2</sub></i>	12.98***	0.2726	-5.0720***	-2.266	-4.510***
<i>lnSMC</i>	4.69***	-0.8055	-2.3586***	-2.503**	-4.582***
<i>lnREN</i>	12.61***	0.2581	-7.2669***	-1.339	-4.292***
<i>lnEG</i>	14.31***	1.0209	-5.7526***	-2.055	-3.456***
<i>lnIND</i>	11.55***	0.6949	-7.4246***	-2.759***	-3.767***
<i>lnEDU</i>	6.98***	2.0970	-4.0073***	-0.890	-3.345***
<i>lnTO</i>	3.14***	0.4313	-6.5335***	-1.365	-4.366***
<b>Westerlund test for cointegration</b>				Statistic	p-value
Variance ration				-1.8511	0.0321

#### 4.3 Baseline Regression and Robustness

Table 6 presents the results from Equations (2) and (3) with columns (1), (2), and (3) as estimates based on the FGLS estimation technique, while columns (4), (5), and (6) are used to demonstrate thorough robustness for estimating models based on the PCSE method. Here we limit to the discussion in regard to our three main informative variables: stock-market capitalization (SMC), renewable energy usage, domestic credit to private sector (DC), and their interaction (SMC\*DC).

**Table 6** FGLS and PCSE results, full sample (Dep Var: CO<sub>2</sub>).

Variables	FGLS Analysis		PCSE Robustness			
	(1)	(2)	(3)	(4)	(5)	(6)
SMC	0.0957*** (2.672)	0.0856** (2.192)	0.119*** (3.590)	0.139*** (3.979)	0.0914*** (2.721)	0.0775*** (3.059)
REN	-0.503*** (-9.699)	-0.438*** (-8.951)	-0.478*** (-13.34)	-0.543*** (-8.833)	-0.448*** (-8.202)	-0.457*** (-10.58)
EG	-0.559*** (-7.887)	-0.591*** (-8.450)	-0.527*** (-9.294)	-0.410*** (-3.793)	-0.435*** (-4.783)	-0.549*** (-7.130)
IND	0.795*** (27.31)	0.831*** (25.96)	0.802*** (35.40)	0.814*** (22.03)	0.839*** (21.92)	0.819*** (29.71)
EDU	-0.393** (-2.558)	-0.493*** (-3.235)	-0.479*** (-3.527)	-0.490*** (-3.090)	-0.617*** (-4.000)	-0.449*** (-3.715)
TO	-0.254*** (-3.036)	-0.219** (-2.527)	-0.269*** (-4.269)	-0.323*** (-4.188)	-0.321*** (-4.112)	-0.259*** (-4.736)
DC		0.204*** (2.997)	0.266*** (4.323)		0.263*** (4.377)	0.338*** (7.183)
SMC*DC			0.252*** (8.893)			0.216*** (9.314)
Constant	-6.779*** (-5.340)	-7.952*** (-6.142)	-7.946*** (-8.602)	-7.649*** (-4.517)	-8.567*** (-5.419)	-8.516*** (-6.737)
Observations	163	163	157	163	163	157
R-squared			0.982	0.913	0.918	0.944
Countries	9	9	9	9	9	9
Wald Statistic	2436	2996	4797	1224	1560	2806

In denotes natural logarithms. Panel-corrected standard errors are reported in parentheses. \*\*\* and \*\* indicate significance at the 1% and 5% levels, respectively.

Across both specifications, SMC is positively and statistically significantly associated with CO<sub>2</sub> emissions. It is observed from baseline (column 1) that, a 1 percent increase in SMC is followed by 0.0957 percent increase in CO<sub>2</sub> emissions. With inclusion of DC in column 2, coefficient of SMC is slightly reduced to 0.0856 and still significant at 5% suggesting that part of stock-market effect operates through the wide credit channel. When the SMC\*DC interaction term is included in column (3), the SMC coefficient is increased to 0.119. Importantly, the interaction SMC\*DC coefficient itself is large and highly significant, indicating that a one-point increase in DC contributes 0.252% to the marginal effect of SMC on CO<sub>2</sub> emissions.

In addition, the positive and significant domestic credit (DC) coefficient in columns (2) and (3) shows that deeper credit markets independently lead to higher emissions, possibly promoting further industrial and energy-intensive activity. Moreover, the significance and positive coefficient of the SMC\*DC interaction are evident, indicating that the carbon-intensifying effect of stock-market growth is even stronger in more advanced credit markets.

Across all specifications, REN has a statistically significant negative association with CO<sub>2</sub> emissions. Demonstrating that promoting investment in renewable energy goes a long way in

mitigating environmental degradation. All models were additionally controlled for economic growth (EG), industrial share (IND), education (EDU), and trade openness (TO). Estimates of the PCSE in columns (4)-(6) have the same sign and similar statistical significance for SMC, DC and SMC\*DC confirming that the core findings are robust with respect to both, heteroskedasticity and contemporaneous correlation among the disturbances in the panel.

In conclusion, stock-market development in Africa leads to increases in CO<sub>2</sub> emissions and, independently and interactively, magnifies this effect. Hence, the demand for green finance frameworks to influence equity and credit expansion towards lower-carbon investments in African capital markets becomes paramount.

## 5. Conclusions

This study uses panel data for nine African economies over 2000-2024 to examine how stock-market development (SMC) and renewable energy consumption (REN) are associated with CO<sub>2</sub> emissions, and test whether domestic credit to the private sector (DC) moderates these relationships. Given evidence of cross-sectional dependence, non-stationarity, and cointegration, the study estimates the models using Feasible GLS (FGLS) and checks robustness with Panel-Corrected Standard Errors (PCSE), controlling for economic growth (EG), industrial share (IND), education (EDU), and trade openness (TO).

There are several important findings. First, stock-market development (SMC) and domestic credit to the private sector (DC) are both positively associated with CO<sub>2</sub> emissions, consistent with earlier findings [54, 55]. Second, the PCSE robustness checks demonstrate that results remain consistent with the main findings that expatriating into equity-based and credit-driven systems can increase energy-intensive activity. Furthermore, REN consistently and significantly reduces CO<sub>2</sub> emissions, which highlights the role renewables play in CO<sub>2</sub> mitigation.

Our finding of the positive SMC\*DC interaction shows that deeper credit markets magnify the carbon-intensifying consequences of stock-market growth. Thus, financial deepening enhanced the transmission mechanism for capital-market development into higher emissions in the region. These results were unchanged between the FGLS and PCSE specifications, which affirms our robustness.

Results have clear policy implications for how African countries can develop financial markets in line with sustainable development. First, governments and market regulators can design green finance instruments - green bonds, sustainability-linked equities, ESG indices, and so on - to tilt equity and credit flows away from fossil fuels and into renewable energy and low-carbon infrastructure.

Second, central banks and financial supervisors can embed climate risk in lending standards, providing advantageous rates or credit guarantee schemes to projects that demonstrate a measurable reduction in emissions. Third, exchanges can require consistent environmental disclosures and carbon accounting for firms traded on their books, improving transparency and directing investor capital to cleaner enterprises.

Finally, policymakers can consider market-wide economic incentives for eco-friendly loans, such as carbon pricing and tax credits or subsidized green loans for lenders and investors. By mainstreaming these consistent policies across the banking, capital, and regulatory sides, African economies can harness financial inclusion and market development as catalysts for both economic growth and climate resilience.

## Abbreviations

CO <sub>2</sub>	Carbon dioxide
DC	Domestic credit to the private sector
EKC	Environmental Kuznets Curve
ESG	Environmental, Social, and Governance
FGLS	Feasible Generalized Least Squares
PCSE	Panel-Corrected Standard Errors
REN	Renewable energy consumption
SMC	Stock market capitalization is used as a proxy for stock market development
WDI	World Development Indicators
CSD	Cross-sectional dependence
VIF	Variance Inflation Factor

## Author Contributions

Bimenyimana Jean-Claude was responsible for the conceptualization, data collection/curation, formal analysis, and writing the original draft of the paper. Dong Meisheng was responsible for validating the results and reviewing/editing the manuscript.

## Competing Interests

The authors declare that the research was conducted without any commercial or financial relationships that could be perceived as potential conflicts of interest.

## Data Availability Statement

The data used in this study are publicly available from the World Bank's World Development Indicators (WDI) database.

## AI-Assisted Technologies Statement

OpenAI's ChatGPT was utilized exclusively to polish the English language and correct grammar. All scientific ideas, data interpretations, and conclusions are entirely the authors' original work. The authors have rigorously reviewed the text and take full responsibility for the manuscript's final content.

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