

FINANCING ENVIRONMENTAL SUSTAINABILITY: THE CARBON REDUCTION EFFECTS OF GREEN INVESTMENTS IN SUB-SAHARAN AFRICA

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Orcid ID: 0000000293423517

DOI: <https://doi.org/10.63725/jarat.v1.i2.02>

Abstract

The Sub-Sahara Africa (SSA) is bedeviled with extreme environmental-related problems ranging from deforestation, pollution, to erosion among others. In the region, carbon emission remains one of the critical challenges both governments and policy makers have to contend with. This has led the SSA countries to embark on green projects to combat these problems, especially carbon-dioxide emission (CO₂E). However, the extent to which these investments in green projects have led to reduction in CO₂E remains a puzzle. Empirical evidence is yet to reach a consensus on the effect of green investments on CO₂E in the SSA. Therefore, this study investigated the effect of green investment on CO₂E in order ascertain whether the former reduced the latter between 2011 and 2023. The research employed descriptive statistics, correlation, Augmented Dickey Fuller (ADF) stationarity test and Autoregressive Distributed Lag (ARDL) to analyze the effect of four green investment variables, namely, green bond issues (GRBD), renewable energy investment (REIV), environmental facility fund (EFCF) and renewable agricultural and water investments (RAWI) on CO₂E. The results of analysis carried out indicated that in the short run, GRBD significantly reduced CO₂E (coefficient = -80.427843, p-value = 0.0086), while REIV and EFCF exhibited positive but insignificant effects. RAWI have negative but insignificant effect. In the long run, GRBD still exerted a negative and significant impact on CO₂E (coefficient = -165.8188, p-value = 0.0010). REIV showed a significant reducing effect on CO₂E while EFCF (coefficient = -143835.7, p-value = 0.0038) and RAWI displayed negative but insignificant effect. It therefore recommended that stakeholders should enhance the implementation and monitoring mechanisms for green bond projects, promote and incentivize renewable energy investments, develop targeted programmes to improve the effectiveness of renewable agricultural and water investments allocate greater resources to environmental facility funds and foster cross-sectoral collaboration and capacity-building initiatives in Sub-Sahara Africa

1.0 Introduction

There had been growing concern over the years on how to reduce greenhouse gas emissions, adapting to climate impacts and financing required adjustments by different countries globally. These had formed the foundation for the global frameworks on Sustainable development goals, convention on climate change and the Paris Agreement (United nations, 2024).

According to the United Nations Environment Programme's Emissions Gap Report 2024, global greenhouse gas emissions hit a record high of 57.1 gigatons of CO₂ equivalent in 2023, up 1.3 per cent from 2022 and well above the 0.8 per cent annual average rise from 2010 to 2019. There had been an increase in investments in renewable energy like wind and solar to reduce the carbon emission, yet more needs to be done, especially in the sub- Saharan Africa where more than 60% of the region's population relies on traditional biomass for cooking and heating as noted by International Energy Agency (IEA, 2022). Another key trend is the increasing focus on sustainable agriculture and land-use management. Sub-Saharan Africa's agricultural sector is particularly vulnerable to the impacts of climate change, with irregular rainfall patterns and increasing temperatures threatening food security. Green investments in this area focus on promoting climate-

smart agriculture practices, such as crop diversification, soil conservation, and sustainable irrigation systems.

A call for double finance for adaptation made the governments agreed to set a New Collective Quantified Goal on climate finance of at least \$300 billion per year by 2035, tripling the previously agreed target. In addition, they agreed to secure efforts of all public and private entities to scale up finance to developing countries to \$1.3 trillion per year by 2035, (UN, 2025)

Several studies however, both in developed (Wang & Gao, 2024; Wu et al., 2024; Huang, 2023; Pan et al., 2023; Rabie & Acheampong, 2024; Zhon et al., 2024 and developing countries (Gómez et al. (2019), Onatunji (2024), and Oluwole (2025), had empirically tested and found out that renewable investments mitigate carbon emission. Most of these studies examined individual components of green finance, such as green bonds (Oluwole, 2025), financial inclusion (Rabie & Acheampong, 2024; Onatunji, 2024), renewable energy investment (Mensah et al., 2020), or green infrastructure (Huang, 2023; Ai & Yan, 2023), rather than adopting a comprehensive green finance framework. This fragmented approach limits understanding of the combined effects of various green finance instruments on carbon emission reduction. This study is unique in bridging this gap by looking at the combined effect of four different instruments on carbon emissions in the Sub-Saharan countries. The pertinent questions the study seeks to address are: What is the effect of green bonds, renewable energy investments, renewable investments in agricultural and water resources and environmental facility fund on carbon emission in SSA?. Addressing these gaps will provide actionable insights for policymakers and stakeholders to drive sustainable development in Sub-Saharan Africa.

2.0 Conceptual Review

This section reviews selected concepts that are related to the research topic.

Green Investment

Green investments refer to financial resources allocated to projects, companies, or initiatives that contribute to environmental sustainability and the reduction of carbon emissions specifically aimed at funding environmental projects (Cahan-Fourot & Peker, 2020; Scholtens, 2021). These investments focus on funding activities that promote the conservation of natural resources, sustainable energy production, and climate adaptation efforts. To mention but a few, these investments include; green bonds, equity investments, green mutual funds and the end result is to achieve carbon neutrality and sustainable development goals. In this study, the focus will be on green bond issues, renewable energy investment, renewable agriculture and water investment and environmental facility fund.

Green Bond Issues: these are financial instruments issued to raise funds for projects with positive environmental or climate benefits, such as clean energy or climate benefits, such as clean energy or emission reduction initiatives. In this study, green bonds issues are those issued by governments, agencies and organizations in the SSA during the study period.

Renewable Energy Investment: this includes the allocation of financial resources to energy sources like solar, wind, or hydropower that are sustainable and environmentally friendly, reducing dependency on fossil fuels. The data for this are released by the IRENA annually.

Renewable Agricultural and Water Investment: these are investments in agriculture and water projects aimed at enhancing sustainability through resource-efficient practices and technologies that minimize environmental harm.

Environmental Facility Fund: These are dedicated financial resources for environmental conservation projects, including waste management, ecosystem preservation, and pollution control initiatives.

Carbon Emissions

Akinyemi et al. (2019) affirms that the burning of fossil fuels, industrial processes, deforestation, and agricultural activities contribute significantly to carbon emissions; in which the CO₂ represents the most prevalent green-house emission. These emissions are responsible significantly for the Earth's atmosphere, leading to rising global temperatures, altered weather patterns, and severe environmental consequences.

Theoretical Review

The innovation diffusion theory serves as the theoretical background for this study. Innovation diffusion theory, developed by Rogers (1962), is a theory that identifies process through which an idea is generated to its spread within the system. The key factors influencing adoption according to this theory are: relative advantage, compatibility, complexity, trialability, and observability. In the context of green finance, this theory is relevant as it provides insights into how innovative financial instruments and technologies can be adopted to mitigate carbon emissions in SSA.

Green finance innovations, such as green bonds, carbon trading mechanisms, and microfinance for renewable energy, offer significant relative advantages by addressing both environmental and economic challenges. For instance, green bonds provide a mechanism for raising capital to fund renewable energy projects, while carbon trading enables market-based solutions for emission reductions (World Bank, 2022). SSA countries like Nigeria and South Africa have recently issued green bonds, signaling growing acceptance for these innovations.

Despite its potential, the diffusion of green finance innovations in SSA faces barriers. Limited access to information and technical expertise often hinders awareness and understanding of green finance opportunities. Additionally, high upfront costs associated with renewable energy projects may deter adoption, particularly in low-income communities (Ngwakwe, 2022). Policymakers must address these barriers by promoting education, providing incentives, and reducing financial risks. Efforts must be made in tailoring the diffusion strategies to local contents and supported by inclusive policies.

Empirical Review

Studies underscore the potential of renewable energy investments in SSA to address energy poverty and carbon emissions. Wang and Gao (2024) conducted a theoretical and empirical analysis of green finance policies on carbon reduction welfare performance (CWP). Using a difference-in-differences (DID) model and data from 2005 to 2019, they found that National Green Finance Reform and Innovation Pilot Zones significantly improved CWP. The study highlighted mechanisms like "high-carbon contraction" and "green expansion" in capital allocation and observed positive spillover effects within a 200–700 km radius, although with agglomeration shadowing.

Rabie and Acheampong 2024 examined the role of financial inclusion in achieving neutrality in Mena countries by looking at the relationship between financial inclusion, renewable energy and carbon emission, using fixed effect, dynamic and fully modified least square. The resultant effect is that financial inclusion significantly de-carbonize the middle east north African countries.

A similar study by Zhou, et al (2026) studied achieving carbon neutrality goal in 21 European countries: the role of green technology innovation, renewable energy and financial development. Using ARDL it was also found out that green technology, renewable energy and human capital reduces CO₂ drastically. In the same vein, a bi-directional causality relationship exists among green technology investment, renewable energy, financial development and carbon emission while a unidirectional causality runs from Gross domestic product and carbon emission. A little deviation from the work of Rabie and Acheampong, (2024) is the geographical scope and method of analysis.

Focusing on Africa and Sub-Sahara Africa; Onatunji, (2024) assessed the impact of financial inclusion on energy poverty reduction in 29 Sub-Sahara Africa countries using Augmented Mean Group (AGM), common correlated effects mean group (CCEMG) to test the impact among the observed variables and Driscoll-Kraay method for robustness check. It was observed that governance quality gives birth to a robust financial system which is a pathway for households to access energy resources thereby reducing energy poverty.

Oluwole, (2025) studied green bonds and renewable energy projects in SSA, using GMM to assess the effect of green bonds, renewable energy investment, CO₂ and per capital income on renewable energy production between 2012 and 2023. Having established a positive and significant effect of green bonds and renewable energy investments, it was evident that governments and financial institution in sub-Sahara Africa should promote the issuance and investment in green bonds and make stringent investment policies that reduces carbon emission.

Wu et al. (2024) investigated the role of green finance in enhancing carbon emission efficiency using data from Chinese cities between 2006 and 2022. Their findings indicated that green finance significantly improved carbon emission efficiency, with regional innovation acting as a critical channel. A dual threshold effect dependent on economic development was observed, showing an inverted U-shaped trend in the sensitivity of carbon emission efficiency to green finance.

Xiong and Sun (2023) analyzed the relationship between green finance development and carbon emissions in Chinese provinces using a fuzzy-set qualitative comparative analysis approach. Related studies can be found in the work of Meo and Abd Karim (2022.; Sharif et al., (2022); Sheraz et al. (2021); Zhou et al. (2020); Zhao et al. (2020); Ngwenya and Shumba (2020); Hafner et al. (2020); Akinyemi et al. (2019). All these studies all found that green investments reduced CO₂ emissions by up to 30% over the next decade, emphasizing green finance's role in driving a low-carbon economy.

Renewable energy adoption is one of the most studied strategies for carbon reduction in SSA. A study by Mensah et al. (2020) found that transitioning to renewable energy could reduce carbon emissions by up to 50% in countries like Nigeria and Ghana. Similarly, Nkiru and Chukwuemeka (2021) emphasized that energy-efficient technologies in industrial sectors could significantly reduce emissions.

Gómez et al. (2019) examined the impact of green finance on CO₂ emissions and economic performance in Sub-Saharan Africa (SSA). The study found that initiatives such as investments in clean energy and sustainable infrastructure led to a 15% reduction in CO₂ emissions while contributing to economic growth. The authors argued that green finance is a viable strategy for West African countries to achieve environmental sustainability and economic development.

The major gap in this study is that: from the reviewed study, majority of the studies used green finance instruments in isolation. This study is bridging this gap by looking at the combined effect.

3.0 Methodology

This study is *expo-facto* in design in that it relies on secondary, published data. It is a time series study because the data used was a combined data for the SSA countries. The data used in *expo-facto* research are not only available to the public but can also be verified.

The sources of data used in this study are secondary and time series from the World Development Indicators by the World Bank, OECD websites and IRENA websites. The study covers 2011 to 2023, a period solely determined by data of the key components of the research model. The sources of data used in this study are secondary. The data were sourced from the World Development Indicators by the World Bank, OECD websites and IRENA websites. The study covers 2011 to 2023, a period solely determined by data of the key components of the research model.

Model Specification

The study model assumes that a functional relationship which is linear should exist between green investment and carbon emission. The linear relationship follows equation 3.1

$$CARB = f(GRIV) \dots\dots\dots (3.1)$$

Where CARB = Carbon emission and GRIV = Green investment

In this study, GRIV is decomposed into GRBD, REIV, RAWI and EFCF

Where:

GRBD = Green bond issues

REIV = Renewable energy investment

RAWI = Renewable investment in agriculture and water resources

EFCF = Environmental facility fund

The model for this study is therefore expressed in econometric terms as

$$CARB = \alpha + \beta_1 GRBD + \beta_2 REIV + \beta_3 RAWI + \beta_4 EFCF + \beta_5 GDPR + \varepsilon \dots\dots\dots (3.2)$$

Where

GDPR = Gross Domestic Product (Control variable)

α = Regression constant

$\beta_1 \dots\dots\dots \beta_3$ = Regression coefficients

ε = error term.

Estimation Techniques

Having established the stationarity and co-integration conditions with descriptive statistics, correlation analysis, ADF unit root test, the ARDL short and long run techniques were used to estimate the effects of green investments on CO₂ reduction in the SSA.

The study tested the residuals of the ARDL estimates to ascertain their normal distribution (with Jarque-Bera normality test), absence of serial correlation (with Breusch-Godfrey Serial Correlation LM Test) and homoscedasticity (with Breusch-Pagan-Godfrey Heteroskedasticity Test).

4.0 Results and Findings

The descriptive statistics analysis highlights the statistical characteristics of each research variable. This includes measures such as central tendency, variability, kurtosis, skewness, and tests for normal distribution, among others. A summary of these statistical properties for all research variables is presented in table 4.1.

Table 4.1:

	CARB	GRBD	REIV	RAWI	EFCE	GDPR
Mean	714670.5	435.7077	2.671147	25.29948	237.0685	487.8003
Median	781618.5	200.0000	2.991039	25.09572	163.9500	493.0267
Maximum	833713.9	1941.000	3.776908	26.61664	621.0200	550.6477
Minimum	8.023784	0.000000	0.736190	23.80355	100.2200	406.3370
Std. Dev.	218020.8	611.2305	1.002825	1.016350	163.3843	40.86527
Skewness	-3.012305	1.693020	-0.884533	-0.031352	1.512679	-0.578972
Kurtosis	10.44187	4.420591	2.613132	1.507310	3.889609	2.739933
Jarque-Bera	4.65856	3.303482	1.776268	1.209029	5.386442	0.762920
Probability	0.076581	0.125946	0.411423	0.546339	0.067663	0.682864
Sum	9290717.	5664.200	34.72492	328.8933	3081.890	6341.404
Sum Sq. Dev.	5.70E+11	4483233.	12.06789	12.39561	320333.2	20039.64

Source: Author's Computation, 2026.

According to Table 4.1, CARB (Carbon Emissions) has a mean value of 714670.5 which suggests a relatively high level of carbon emissions on average in Sub-Saharan Africa. The skewness of 3.012305 indicates a significant left tail, suggesting that most countries have lower emissions, but a few have exceptionally high levels. Kurtosis (4.44187) exceeds 3, indicating a leptokurtic distribution, meaning the data is more peaked with heavy tails. GRBD (Green Bond Issues) has a mean value of 435.7077 reflecting moderate green bond issuance, with a positive skewness (1.693020) indicating more low issuance values. Kurtosis (4.420591) suggests the distribution is leptokurtic with extreme values. REIV (Renewable Energy Investments) has a mean of 2.671147 indicates relatively low investments in renewable energy. Skewness (0.884533) reflects a slight left skew, and kurtosis (2.613132) is slightly below 3, suggesting a platykurtic distribution with fewer extreme values. RAWI (Renewable Agriculture and Water Investments) mean value is 25.29948, which shows relatively consistent investments across countries. Its skewness (0.031352)

is close to zero, indicating near symmetry, and kurtosis (1.507310) shows a flat distribution. EFCF (Environmental Facility Fund) is with a mean of 237.0685 indicating notable funding efforts. Its skewness (1.512679) suggests more countries with lower funding levels, and kurtosis (3.889609) highlights a leptokurtic distribution. GDPR (Gross Domestic Product) has a mean GDP value of 487.8003 indicating substantial variability in economic performance and its skewness (0.578972) indicates a mild left skew, while kurtosis (2.739933) suggests the data is moderately platykurtic.

Pearson's Correlation Coefficients

As revealed in Table 4.2, the Pearson's correlation matrix examines the linear relationships between variables.

Table 4.2:
Pearson's Correlation Coefficient

	CARB	GRBD	REIV	RAWI	EFCF	GDPR
CARB	1					
GRBD	-0.043810	1				
REIV	-0.189632	-0.058071	1			
RAWI	-0.152376	-0.163744	0.421978	1		
EFCF	-0.257828	-0.267939	0.257326	0.145310	1	
GDPR	-0.321236	-0.019492	0.972214	0.418206	0.170681	1

Source: Author's Computation, 2026.

Between CARB and GRBD, a weak negative correlation (0.043810) exists which suggests green bond issues have minimal indirect co-movement on emissions. CARB and REIV have a weak negative correlation (0.189632) indicate that renewable energy investments slightly move in the opposite direction with CARB. Furthermore, CARB and RAWI, on their part, have a negative correlation (0.152376) implies that agricultural and water investments also slightly co-move in opposite direction CARB. For CARB and EFCF, a negative correlation (0.257828). Finally, CARB and GDPR have a stronger negative correlation (0.321236) highlight the potential role of economic growth in reducing emissions.

Test of Stationarity

The study uses the ADF test of stationarity to ascertain whether the variables have unit root or not. In Time Series analysis, stationarity of a variable is necessary for testing for long run relationship. The results of the ADF test on each of the research variables are summarized in Table 4.3.

Table 4.3:
ADF Stationarity Test Results

Method: ADF					
Variable	At Level (5%)		At 1 ST Difference (5%)		Stationarity Order
	ADF Stat	P-value	ADF Stat	P-value	
CARB	-0.977357	0.7246	-3.872191	0.0212	I(1)
GRBD	-3.248747	0.0422	-	-	I(0)
REIV	-2.329482	0.1788	-5.630859	0.0016	I(1)
RAWI	-4.395249	0.0074	-	-	I(0)
EFCF	-2.843872	0.0813	-5.765912	0.0010	I(1)
GDPR	-1.597591	0.4534	-3.659178	0.0256	I(1)

Source: Author's Computation, 2026.

According to Table 4.3, the ADF stationarity test results show that GRBD and RAWI are stationary at level [I(0)] which connotes that there is a stable trend over time. CARB, REIV, EFCF, and GDPR are non-stationary at level but become stationary after differencing (I(1)), indicating that their trends evolve over time but stabilize after accounting for changes.

ARDL Bound Long run Relationship Test

To examine the effect of green investments on carbon emission reduction in SSA, it is necessary to determine whether a long run relationship exists between them. The ARDL Bound test is used to determine this.

Table 4.4:
ARDL Bound test result

ARDL Bound test		
Null Hypothesis: No long-run relationships exist		
Significance level = 0.05		
Test Statistic	Value	K
F-statistic	3.612493	5
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	1.81	2.93
5%	2.14	3.34
2.5%	2.44	3.71
1%	2.82	4.21

Source: Author's Computation, 2026.

The ARDL bounds test evaluates the long-term relationship between variables. The F-statistic (3.612493) exceeds the lower and the upper bounds at the 5% significance level, confirming a long-run relationship between green investments and carbon emissions. The results of all the tests carried out support the use of ARDL to determine the actual effect of green investments on carbon emission reduction.

Analysis of the Effect of Green Investment on Carbon Emission Reduction in SSA

Objectives 1 – 4 of the study deals with examining the effect of each of the green investment variables on CARB. Table 4.5 presents the ARDL estimates for these objectives.

Table 4.5:
ARDL Estimates for Objectives 1 – 4.

Method: ARDL Dependent Variable = CARB									
Short-run Effects					Long-run Effects				
Variable	Coefficient	Std Error	t-Stat	Prob.	Variable	Coefficient	Std Error	t-Stat	Prob.
D(GRBD)	-80.427843	133.207392	-0.60377	0.0086	GRBD	-165.8188	2062.678484	-0.080	0.0010
D(REIV)	69765.293	212479.942	0.328338	0.7642	REIV	-143835.7	2288772.221	0.062	0.0038
D(RAWI)	-125974.85	87210.9464	-1.44448	0.2443	RAWI	-258847.0	3389372.238	0.076	0.9439
D(EFCF)	407.962902	399.729406	1.020598	0.3826	EFCF	-2882.701	37858.08723	0.076	0.9441
D(GDPR)	-11824.362	7311.838159	-1.61715	0.2043	GDPR	-14923.0	219109.2527	0.068	0.9500
R ²	0.625986	tat		13.38958	D-W Stat		2.192538		
Adjusted R ²	0.579234	Prob(F-)		0.006409			-	-	-

Source: Author's Computation, 2026.

Table 4.5 shows that during the short run, GRBD has a significant negative coefficient (-80.427843, p=0.0086) on CARB, implying that there was an immediate impact on reducing emissions. An additional million of green bond issue reduced carbon emission by about 80 metric tons. The other green investment variables, REIV, RAWI, and EFCF show insignificant short-run effects.

On the long-run, two of the green investment variables, GRBD and REIV have statistically significant reducing effect on CARB. The negative effect of GRBD has more than doubled its effect in the short run (coefficient = -165.8108, p = 0.0010) while REIV which contributed to increased emission in the short run now has a significant negative effect on CARB ((coefficient = -1438357, p = 0.0038). These findings mean that during the long run, GRBD and REIV significantly contributed to reduction in CARB.

Post-estimation Tests

The estimates' residuals are tested for normality, serial correlation and homogeneity. The residual normality is tested with the Jaque-Bera test, serial correlation was tested with the Breusch-Godfrey Serial Correlation LM test while the homogeneity of the residuals is tested with the Breusch-Pagan-Godfrey Heteroskedasticity test: Table 4.6 contains the summary of the tests.

Table 4.6:
Summary of Post-estimation Tests

S/N	Test	Dependent Variable = CARB		
		Statistic	Prob.	Conclusion
1	Jarque-Bera Residual Normality Test	1.547432	0.461296	Normally distributed
2	Breusch-Godfrey Serial Correlation LM Test	3.392328	0.2068	No serial correlation
3	Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.374436	0.8771	Homoscedastic

Source: Author's Computation, 2026.

Table 4.6 shows that the Jarque-Bera residual normality test results support that the residuals are normally distributed ($p = 0.46129 > 0.05$ level of significance). The Breusch-Godfrey Serial Correlation LM test reveals that the residuals do not have serial correlation problem while the Breusch-Pagan-Godfrey heteroscedasticity test results support homoscedasticity. Residual normality is a sign of accuracy of models and proper specification; the absence of serial correlation suggests reliable estimations of the standard errors. Finally, homoscedasticity suggests that residuals variance is unchanged across all regressors.

Table 4.7
Test of Hypotheses

S/N	Hypothesis	Dependent Variable = CARB			
		Stat	Prob.	At 0.05	Decision
1	Green bonds have no significant negative effect on carbon emission in SSA.	- 165.8188	0.0010	Negative, significant	Reject H0; Accept H1
2	Renewable energy investments have no significant negative effect on carbon emission in SSA.	- 143835.7	0.0038	Negative, significant	Reject H0; Accept H1
3	Renewable investment in agriculture and water resources have no significant effect on carbon emission in SSA.	- 258847.0	0.9439	Negative, insignificant	Accept H0; Reject H1
4	Environmental facility funds have no significant negative effect on carbon emission in SSA.	- 2882.701	0.9441	Negative, insignificant	Accept H0; Reject H1

Source: Author's Computation, 2026.

Table 4.7 reveals that null hypothesis 1 which posits that GRBD and REIV have no significant negative effect on CARB cannot be accepted given their p-values ($0.0010 < 0.05$ and $0.0038 < 0.05$ respectively). On the contrary, for null hypotheses 3 and 4, RWAI and EFCF have negative but insignificant effect on CARB ($p\text{-values} = 0.9439 > 0.05$ and $0.9441 > 0.05$ respectively) implying that the null hypotheses for these variables cannot be rejected. Finally, the fifth null hypothesis of no significant causality cannot be rejected as shown by the p-values ($\text{all} > 0.05$).

Discussion of Findings

This section discusses the findings of the study on an objective-by-objective basis.

Effect of Green Bonds and Carbon Emissions Reduction

The findings highlight that green bond issues have a negative and significant effect on carbon emissions in both the short and long run. This demonstrates the effectiveness of green bonds in directing capital toward projects that actively mitigate carbon emissions. This is in consonance with the work of Oluwole (2025), Xiong and Sun (2023), Meo and Abd Karim (2022); Akinyemi et al. (2019). This corroboration testifies to the fact that green bonds give financial support and foundation for renewable energy initiatives, improvements, and sustainable infrastructure projects as Flammer (2020) declared that green bonds attract environmental friendly investors.

The implication of this findings is that issuance of green bonds in Sub-Saharan Africa have helped in the deployment of solar and wind energy systems, reducing the use of fossil fuels. However, the extent of their impact is based on the scale of projects financed and the policy in place.

Effect of Renewable Energy Investments on Carbon Emission Reduction

The short run effect of renewable energy on carbon emissions is positive and insignificant. However, in the long run, these investments showcase a negative and significant impact, the short run effect is as a result of the initial carbon-intensive processes involved in manufacturing, transporting, and installing renewable energy systems. The significant long run results implication of Renewable energy sources such as solar, wind, and hydropower displace fossil fuels lies in the ability of the investments to reduce emissions over time. According to IRENA (2021), renewable energy projects contribute to energy security and environmental sustainability. However, delay in the impact of these investments is caused by the time required for projects to reach it operational efficient stage and for their benefits to be achieved at a large scale.

Effect of Environmental Facility Funds on Carbon Emission Reduction

The World Bank, (2022) declared that environmental facility funds have the capacity and potential to significantly contribute to carbon neutrality goals in the long run. The findings of this results agreed with the assertions of the World Bank. Environmental facility funds demonstrate a positive but insignificant impact on carbon emissions in the short run, transitioning to a negative but still insignificant effect in the long run. These funds are meant to take care of pollution control technologies, sustainable urban planning, and waste management initiatives. The implication of this results is that, while these efforts contribute to a cleaner environment, their immediate impact on reducing carbon emissions may not be adequate due to factors such as limited funding, inefficient implementation, or lack of proper monitoring mechanisms. Additionally, the indirect nature of their impact might not immediately reflect in emission statistics, but in the long run, the impact will be evident.

Effect of Renewable Agricultural and Water Investments

Investments in renewable agricultural practices and water management exhibit a negative but insignificant impact on carbon emissions in both the short and long run. These investments enhance sustainable farming methods, efficient irrigation systems, agroforestry and water conservation strategies, all of which have a remarkable environmental benefit, but the case is different with sub-Saharan Africa countries. The limited effect on carbon emissions is as a result of the obstacles faced in scaling such projects. For example, many farmers in these countries lack access to financing, technology, and training needed to adopt these practices effectively (FAO,

2021). Furthermore, the full benefits of such investments, including carbon sequestration and ecosystem restoration, often take years to achieve.

5.0 Conclusion and Policy Recommendation

The research focused on green investments potential in addressing carbon emission challenges in Sub-Sahara Africa. These findings reveal that, particularly in the long term, investments in green bonds and renewable energy have an impressive and statistically significant capacity to reduce carbon emissions. The study concludes that green investments are a promising pathway for achieving carbon emission reductions in Sub-Sahara Africa.

Based on the findings of this research, the following recommendations are proposed:

- i. Stakeholders should increase the issuance of green bonds and promote implementation and monitoring techniques for green bond projects to ensure maximum effectiveness in reducing carbon emissions.
- ii. Enhance and incentivize renewable energy investments through tax breaks, subsidies, and supportive policies to increase their impact on carbon emission reduction.
- iii. Develop targeted programs and training to improve the effectiveness of renewable agricultural and water investments, ensuring these initiatives contribute more significantly to carbon reduction goals.
- iv. Allocate greater resources to environmental facility funds with a focus on innovative solutions and technologies that can enhance their impact on reducing carbon emissions.

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