Impact of Climate Financing on Industrial Sector Growth in Selected Countries in Sub-Saharan Africa

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ABSTRACT

This paper examined the impact of climate financing on industrial sector growth in selected Sub-Saharan African countries, focusing specifically on how different components of climate finance, namely Climate Equity Investment Funds, Climate Loans (Debt), and Climate Bilateral and Multilateral Grants/Aid, influenced industrial sector growth between 2009 and 2024. The study adopted a longitudinal research design and utilized secondary panel data across five Sub-Saharan African countries, South Africa, Nigeria, Kenya, Ethiopia, and Senegal. The fixed effects regression model was employed following the result of the Hausman test, which confirmed the existence of correlation between country-specific effects and explanatory variables. Findings revealed that Climate Loans and Climate Grants had a statistically significant and positive impact on industrial sector growth, indicating their effectiveness in supporting infrastructure development, technological upgrades, and capacity-building. In contrast, Climate Equity Investment Funds had a negative and statistically insignificant impact, suggesting that equity flows remained too volatile or inadequate to support sustained industrial transformation. Based on these outcomes, the study recommended that national governments collaborate with institutions such as the African Development Bank, Green Climate Fund, and national development banks to expand concessional loan access and scale up blended equity financing. Additionally, ministries of environment and industry should work with United Nations Industrial Development Organization and United Nations Economic Commission for Africa to attract and effectively manage climate grants. Strengthening institutional capacity and aligning climate finance strategies with industrial policy objectives were also recommended to ensure the long-term sustainability of industrial growth in the region.

Keywords: Climate Finance, Industrial Growth, Equity Investment, Climate Loans, Climate Grants

JEL Codes: Q56, O14, G23, H81, F35

INTRODUCTION

Climate financing has emerged as a key mechanism in the global pursuit of sustainable development, particularly in light of the escalating impacts of climate change. The global climate finance system encompasses a wide array of funding instruments designed to support mitigation and adaptation initiatives across various sectors, especially in developing economies. As noted by the OECD (2024), climate finance includes financial flows that aim to reduce greenhouse gas emissions and foster climate resilience. These funds are mobilized through multiple channels, most notably Climate Equity Investment Funds, Climate Loans (Debt Instruments), and Climate Bilateral and Multilateral Grants/Aid. Climate Equity Investment Funds typically involve private or public sector investment in low-carbon, climate-resilient infrastructure and technologies. Climate Loans represent debt financing allocated to governments or institutions to implement climate-related projects, often with concessional terms. In contrast, Bilateral and Multilateral Grants are non-repayable funds provided through international cooperation frameworks to support climate adaptation and mitigation in recipient countries (Adeleke & Ogunbiyi, 2023).

In Sub-Saharan Africa, climate finance has gained attention over the past two decades, although unevenly across countries. South Africa, Kenya, Nigeria, Ethiopia, and Senegal present varied experiences in climate finance inflows, reflecting differences in institutional capacity, governance frameworks, and economic priorities. For instance, Nigeria experienced a dramatic surge in Climate Equity Investment Fund inflows in 2015, peaking at $42.66 billion, yet saw a sharp contraction in subsequent years, falling to $2.13 billion by 2024. Ethiopia, on the other hand, saw a more consistent increase, rising from $929.57 million in 2009 to $1.28 billion in 2024, with notable peaks in 2015 ($2.48 billion) and 2016 ($2.80 billion). In terms of Climate Loans, South Africa's debt inflow increased significantly from $110.22 million in 2009 to $421.67 million in 2024, highlighting a growing reliance on external borrowing to finance climate adaptation projects. Senegal's use of Bilateral and Multilateral Grants showed a steady upward trend, rising from $1.55 billion in 2009 to $1.94 billion in 2024, reflecting donor confidence and increased institutional capacity to absorb and utilize climate funds (OECD, 2024).

While climate financing aims to bolster environmental resilience, its implications for economic sectors, especially the industrial sector, are essential (Ezie, et al., 2025). The industrial sector, encompassing manufacturing, construction, mining, and utilities, is globally recognized as a critical engine of economic growth, job creation, and structural transformation. In Sub-Saharan Africa, industrial development holds particular promise as a pathway to economic diversification, improved productivity, and inclusive development. Ideally, the sector should contribute significantly to gross domestic product (GDP), generate large-scale employment, enhance export performance, and reduce dependence on primary commodities (Bai & Wang, 2024).

However, the reality is that the industrial sector in many Sub-Saharan African countries is not performing at its optimal level. Although some progress has been made, the sector continues to struggle with limited access to finance, infrastructure bottlenecks, weak technological capacity, and vulnerability to climate shocks. For instance, while Nigeria's industry value added reached 33.24% of GDP in 2024, it had fallen to as low as 18.17% in 2016 despite significant capital inflows (OECD, 2024). Kenya, on the other hand, experienced a steady decline in its industrial output from 19.66% of GDP in 2011 to just 16.45% in 2024, indicating a persistent erosion of industrial competitiveness (World Bank, 2025). These figures demonstrate that most countries in the region are falling short of their industrial growth potential.

Therefore, given that climate finance serves as a critical enabler of sustainable investment, technological advancement, and sectoral transformation, it is imperative to examine how core components of climate finance, namely Climate Equity Investment Funds, Climate Loans (Debt), and Climate Bilateral and Multilateral Grants/Aid, have influenced the performance of the industrial sector in Sub-Saharan Africa. Therefore, it is in the interest of this study to conduct an in-depth analysis of how these distinct instruments of climate finance have impacted industrial sector growth, measured as industry value added as a percentage of GDP, across selected Sub-Saharan African countries, South Africa, Nigeria, Kenya, Ethiopia, and Senegal, over the period 2009 to 2024.

LITERATURE REVIEW

Conceptual Review

Climate Financing

Climate financing has gained increasing prominence in contemporary development discourse as both a mechanism for environmental sustainability and an instrument for economic transformation, particularly in developing regions such as Sub-Saharan Africa. Broadly, climate finance refers to local, national, or transnational financing, drawn from public, private, and alternative sources, that supports mitigation and adaptation actions to address climate change. According to Bai and Wang (2024), climate finance encompasses financial flows directed toward activities that reduce greenhouse gas emissions or enhance resilience to the adverse effects of climate variability. These financial flows are often channeled into critical sectors such as energy, agriculture, water resources, and, more recently, industrial development, reflecting the growing realization that green financing must be interwoven with structural economic change. In this context, understanding the composition and function of the primary instruments of climate finance, Climate Equity Investment Funds, Climate Loans

(Debt), and Climate Bilateral and Multilateral Grants/Aid, is essential to evaluating their influence on economic sectors, including industry.

Climate Equity Investment Funds are a form of climate finance where public or private entities invest capital directly into projects or companies with strong environmental and climate-focused outcomes. These funds often target renewable energy, sustainable manufacturing, and green infrastructure projects in developing economies. As defined by Twum et al. (2024), Climate Equity Investment Funds are long-term, patient capital contributions that share both the financial risks and potential returns of low-carbon and climate-resilient investments. Unlike loans or grants, equity investments do not require repayment but instead give the investor ownership stakes in the financed projects. These funds play a catalytic role in de-risking green projects and attracting further private sector capital by demonstrating the commercial viability of climate-aligned industrial ventures (Osiobe, 2019).

Climate Loans (Debt) are another essential form of climate finance. These are borrowed funds extended to governments or enterprises to finance climate-related projects, with repayment obligations typically spread over a long period. Such loans can be concessional, involving low-interest rates and favourable terms, or non-concessional, structured similarly to market-based financing. Sossa (2024) argues that climate-related debt instruments are increasingly used for large-scale infrastructure investments such as clean energy plants, green transport networks, and sustainable industrial parks. These loans are particularly appealing for governments in developing regions that lack sufficient fiscal space to support capital-intensive industrial transitions. However, their use also raises concerns regarding debt sustainability, especially in low-income countries already burdened with high external debt levels.

Climate Bilateral and Multilateral Grant/Aid refers to non-repayable financial assistance provided by donor governments, international organizations, or multilateral development banks to support mitigation and adaptation efforts in developing countries. These grants are often tied to specific programs or institutional strengthening activities that may not yield immediate financial returns but are crucial for long-term climate resilience and inclusive development. Adepoju and Nwokocha (2022) define climate grants as the foundational arm of international climate finance architecture, particularly effective in addressing adaptation needs and capacity-building gaps. Unlike equity and loans, grants reduce fiscal strain and serve as enablers of policy and institutional reforms necessary for broader climate-compatible industrial development.

For the purpose of this study, climate financing is conceptually defined as the totality of financial inflows, including Climate Equity Investment Funds, Climate Loans (Debt), and Climate Bilateral and Multilateral Grants/Aid, mobilized to support climate-resilient and low-carbon industrial development.

Industrial Sector Growth

Industrial sector growth represents a fundamental component of economic development and structural transformation, particularly in developing economies where industrialization serves as a pathway from agriculture-based to manufacturing and service-oriented economic structures. According to Adeleke and Ogunbiyi (2023), industrial sector growth is defined as "the sustained expansion of manufacturing, construction, mining, and utilities sectors measured through increases in value-added contributions to gross domestic product, employment generation, technological advancement, and productivity improvements that collectively drive structural economic transformation and enhance competitiveness in global markets.

Bandyopadhyay and Sharma (2022) define industrial sector growth measurement as "the systematic assessment of industrial development through quantitative indicators including industry value-added as percentage of GDP, manufacturing output growth rates, industrial employment generation, productivity indices, and technological sophistication measures that collectively provide comprehensive evaluation of industrial sector performance and contribution to overall economic development.

Nguyen and Patel (2023) conceptualize industrial sector growth as "the process through which economies transition from primary sector dependence toward manufacturing and high-value industrial activities, characterized by increasing industrial value-added shares of GDP, rising productivity levels, technological upgrading, and industrial diversification that collectively contribute to sustained economic growth, employment creation, and poverty reduction.

However, Okon and Udoh (2024) defined digital industrial growth as the transformation of industrial sectors through adoption of digital technologies, automation systems, data analytics, and artificial intelligence applications that enhance production efficiency, product quality, supply chain optimization, and customer responsiveness while enabling participation in digital economy and Industry 4.0 initiatives.

This paper adopts a working definition of industrial sector growth as the sustained expansion of manufacturing, construction, mining, and utilities sectors measured primarily through increases in industry value-added as percentage of GDP, while incorporating employment generation, productivity improvements, technological advancement, and environmental sustainability dimensions that collectively contribute to structural economic transformation, competitiveness enhancement, and sustainable development outcomes in Sub-Saharan African economies.

Theoretical Underpinning

The theoretical underpinning for this paper is the Solow Growth Model, originally propounded by Robert Solow in 1956. The Solow Growth Model, also known as the neoclassical growth model, provides a foundational framework for understanding long-term economic growth based on capital accumulation, labour or population growth, and technological progress. Solow's model posits that economic growth is driven primarily by increases in capital and labour, but that sustained long-term growth in output per worker can only be achieved through technological advancement. The model emphasizes that while capital accumulation can spur growth in the short run, diminishing returns to capital set in over time, making technological innovation the critical determinant of long-term productivity and income growth.

In the context of this study, the Solow Growth Model is significant as it provides theoretical justification for analysing how climate finance contributes to industrial sector growth through capital investment. Climate finance instruments such as Climate Equity Investment Funds, Climate Loans, and Climate Grants represent forms of capital infusion that can raise the industrial sector's productive capacity. According to Bai and Wang (2024), when directed toward industrial development, such investments increase the capital stock and enhance productivity, particularly when complemented by technological improvements and institutional efficiency. This interpretation aligns with Solow's assertion that exogenous technological progress, supported by capital accumulation, is the engine of sustainable growth.

One of the strengths of the Solow Growth Model is its clear delineation of the roles of capital, labour, and technology in growth, allowing for empirical analysis of how external financing mechanisms like climate finance can affect sectoral development. The model also provides a basis for understanding differences in growth paths between countries by highlighting the importance of savings rates, investment in physical capital, and access to technology. This makes it especially relevant for Sub-Saharan African countries that receive varying levels and types of climate finance, and exhibit differing industrial outcomes.

However, the model has faced several criticisms. Scholars such as Romer (1990) and Lucas (1988) argue that the Solow model treats technological change as exogenous, failing to explain how or why innovation occurs. This limitation reduces its capacity to inform policies that seek to generate endogenous growth through innovation and human capital development. In addition, Acemoglu and Robinson (2012) criticize the model for its inadequate treatment of institutions, noting that institutional quality and governance play a fundamental role in determining whether capital and technology lead to real economic transformation. These criticisms suggest that while the Solow Model offers valuable insights into capital-driven growth, it may overlook the importance of policy, institutions, and innovation systems that are essential for translating climate finance into sustained industrial growth.

Nonetheless, the relevance of the Solow Growth Model to this study lies in its analytical clarity regarding capital investment and growth outcomes. By treating climate finance as a form of capital accumulation targeted at the industrial sector, the model provides a logical framework for investigating how different financing instruments impact industrial value added in selected Sub-Saharan African countries. Thus, this study is rooted in the Solow Growth Model, employing it to explore how the infusion of climate finance contributes to industrial sector growth and broader economic development in the region.

Empirical Review

Understanding the impact of climate financing on industrial sector growth has become an increasingly relevant subject in development economics, especially in the context of Africa’s push for sustainable industrialization. Various empirical studies have attempted to explore this relationship using different proxies, timeframes, methods, and geographic scopes. This review presents five recent empirical contributions to this field, highlighting their findings and methodological limitations.

In a cross-country analysis, Twum et al. (2024) investigated the influence of climate finance on sectoral transformation in five African economies, South Africa, Kenya, Nigeria, Ethiopia, and Senegal, covering the period from 2000 to 2020. The authors employed a panel data regression model using Climate Equity Investment, Climate Loans, and Climate Grants as independent variables, and sectoral GDP contributions as the dependent variables. Their findings showed that Climate Equity Investment Funds had a statistically significant positive effect on industrial sector growth, while Climate Loans demonstrated a delayed but ultimately positive impact. Climate Grants, although substantial in volume, showed mixed results due to implementation inefficiencies. The study was limited by its use of aggregated sectoral data that did not isolate industrial sub-sectors, making it difficult to draw conclusions specific to manufacturing or construction components of industry.

Bai and Wang (2024) conducted a global study that analysed how different types of climate finance influenced structural economic change in low- and middle-income countries between 2005 and 2022. Utilizing a dynamic panel Generalized Method of Moments (GMM) approach, the study assessed the role of Climate Loans, Equity Investments, and Grants in transforming industrial output. The results indicated that equity investments were most effective in economies with stable institutional frameworks, while loans showed stronger impacts in countries with established industrial bases. Climate Grants were positively associated with institutional capacity building but not directly with industrial output. Although comprehensive, the study covered a vast and heterogeneous group of countries, which potentially masked regional disparities and country-specific dynamics, particularly within Sub-Saharan Africa.

In a country-specific study, Adepoju and Nwokocha (2022) examined Nigeria’s climate finance inflows and their influence on industrial sector growth from 2009 to 2020. Using vector error correction modeling (VECM), they analysed annual data on climate-related equity, concessional loans, and grants in relation to Nigeria’s industrial value added. The results showed that Climate Equity Investment Funds had a significant short-run and long-run impact on industrial performance, while Climate Loans positively influenced infrastructure-led growth in the industrial sector. Climate Grants, although consistent, did not show any significant statistical impact, which the authors attributed to the grants' focus on non-industrial sectors like agriculture and health. The study's time frame was relatively short, and it did not account for structural breaks such as policy reforms or global shocks that may have influenced climate finance flows and industrial performance.

A more regional approach was taken by Sossa (2024), who assessed the effect of debt-based climate financing on industrial growth in the West African Economic and Monetary Union (WAEMU) between 2008 and 2021. The study used fixed effects panel regression and focused solely on Climate Loans as the explanatory variable. Results indicated a strong positive association between concessional loans and industrial development, particularly in energy-intensive sub-sectors like manufacturing and construction. However, by omitting equity and grant-based financing, the analysis provided a partial view of climate finance’s multidimensional impact on industrial growth. Moreover, the study did not address the institutional factors that could mediate the effectiveness of debt financing in the region.

Osei et al. (2024) investigated how climate finance contributes to industrial diversification in 42 African countries from 2010 to 2022, using a dynamic threshold panel model. Their study focused on industrial dynamics, operationalized through product space analysis and export diversification measures, and assessed the effects of climate equity investments, sector-specific green infrastructure loans, and adaptation grants. Their findings revealed that equity investments only contributed positively when they exceeded an annual threshold of $50 million per country, highlighting the importance of scale in driving structural transformation. Green infrastructure loans had the strongest influence, increasing manufacturing dynamics by 12 percent over five-year periods in economies with pre-existing industrial capacities. Adaptation grants had limited direct impact on dynamics but yielded infrastructure-related spillovers. However, reliance on export-based measures may have introduced bias in countries with large informal sectors. Additionally, the study's scope, while innovative, did not fully address broader industrial indicators like job creation or productivity growth, limiting its application to real-time economic outcomes.

Nakamura et al. (2024) expanded the geographic scope by exploring climate finance effects across 28 Pacific Island and Southeast Asian economies between 2012 and 2023. Employing a spatial panel econometric model, the study assessed renewable energy industrial development, focusing on renewable energy manufacturing, green tech employment, and clean energy exports. Climate resilience bonds were found to have the most pronounced effects in small island states, increasing employment in green sectors by 18 percent over three years. Multilateral adaptation funds showed benefits only in countries with sufficient institutional capacity, while bilateral green assistance produced regional spillovers via cross-border technology flows and supply chain integration. While the spatial modeling was methodologically robust, its assumptions on geographic interdependence may not uniformly hold across diverse economic contexts. Moreover, the narrow focus on renewable energy omitted other industrial sub-sectors that are also key targets of climate finance, limiting the general applicability of the results.

Asante and Mensah (2024) adopted a causal inference approach to assess climate finance's impact on industrial productivity in 38 Sub-Saharan African countries from 2008 to 2023. Using an instrumental variable strategy that exploited exogenous variation from donor fiscal cycles and international climate policy shifts, they estimated the effects of concessional loans, climate investment guarantees, and carbon market mechanisms on manufacturing productivity, applying stochastic frontier analysis. Their results showed that doubling concessional loans improved productivity by 8.5 percent over four years, while investment guarantees generated a 5.2 percent increase, especially in high-risk environments. Carbon market financing showed negligible effects, attributed to weak institutional frameworks. Despite the strength of the identification strategy, the validity of the instruments may be challenged if donor economic cycles also influence industrial outcomes through other channels. Furthermore, the study focused exclusively on productivity, overlooking distributional effects and long-term sectoral transformation.

Rodriguez and Kim (2024) evaluated the moderating role of domestic financial market development in the effectiveness of climate finance across 55 emerging markets between 2009 and 2022. Applying a panel smooth transition regression model, they analysed the interaction between financial market indices and three forms of climate finance: equity funds, green banking, and policy-based lending. Sustainable manufacturing growth, measured by environmental performance and output growth, was the dependent variable. The results showed that equity finance was most effective in countries with mature financial systems, generating a 14 percent growth rate compared to only 3 percent in weaker markets. Green development banking had positive but uneven effects, while climate policy lending outcomes depended on regulatory quality. Despite its contribution to understanding conditional effectiveness, the model's requirement for large samples may reduce its utility in country-specific analysis. Additionally, the financial development indices used might not fully capture informal financial dynamics prevalent in many lower-income countries.

Okafor and Liu (2024) provided firm-level evidence by analysing the effects of climate finance on manufacturing performance in six West African countries between 2015 and 2023. Using a matched treatment-control design, they compared firms receiving climate venture capital, green loans, and technical assistance grants with non-recipients. The study measured revenue, employment, technology use, and environmental compliance. Firms supported by climate venture capital recorded 22 percent higher revenue growth and 16 percent higher employment gains over three years compared to control firms. Green loans produced positive effects, particularly in large and export-focused firms, while technical assistance grants mainly facilitated environmental upgrades and technology adoption. Although detailed, the study faced potential selection bias due to unobservable differences between treated and control firms. Its focus on short- to medium-term outcomes may also underrepresent the full life cycle impact of longer-term climate finance instruments.

In a focused sectoral study, Diallo and Camara (2023) assessed how climate finance impacted industrial energy efficiency in francophone West African nations from 2010 to 2022. Using panel quantile regression, the authors assessed the differential effects of Climate Loans, Equity Investments, and Grants on industrial energy use and productivity. They found that Climate Equity Investment Funds were positively associated with energy-efficient production, particularly in Senegal and Côte d'Ivoire. Climate Loans supported infrastructure modernization but had limited reach in less creditworthy economies. Grants were most effective in promoting institutional reforms rather than direct industrial outputs. The study offered valuable insights but was constrained by data limitations on private sector participation, which is an important channel through which climate finance operates.

Molua and Nchinda (2023) explored climate finance and industrial productivity in Central Africa, focusing on Cameroon and the Democratic Republic of Congo from 2010 to 2022. Using cointegration and error correction techniques, the authors examined the individual and combined effects of Climate Equity Investment Funds, Climate Loans, and Grants on industrial GDP. Their findings showed that equity financing was highly effective in Cameroon, while grants had a more substantial impact in the Democratic Republic of Congo due to donor-led infrastructure initiatives. Loans had mixed results across both countries, depending on repayment terms and project implementation. The study, while insightful, was constrained by limited data availability and inconsistencies in donor reporting, which may have affected the reliability of the findings.

METHODOLOGY

This study adopted a longitudinal research design to investigate the impact of climate financing on industrial sector growth across selected Sub-Saharan African countries from 2009 to 2024. The longitudinal design enabled the analysis of changes and patterns over time. This approach provided a robust framework for capturing temporal variations, identifying lag effects, and establishing potential causal relationships. It also facilitated trend analysis, ensuring that the study accounted for structural shifts, policy interventions, and macroeconomic dynamics that affect both climate finance flows and industrial sector growth over the 15-year period.

The study relied on quantitative secondary data collected over a 16-year period from 2009 to 2024. Data on climate financing, comprising Climate Equity Investment Funds, Climate Loans (Debt), and Climate Bilateral and Multilateral Grants/Aid, were sourced from the OECD (2024), including databases such as the Climate Policy Initiative, Green Climate Fund, and World Bank Climate Investment Funds. Industrial sector growth, measured by industry value added as a percentage of GDP, was obtained from the World Bank's World Development Indicators (WDI, 2025). These reputable and internationally recognized sources ensured data reliability, consistency, and comparability across the selected Sub-Saharan African countries.

In line with the focus of this research, the study drew from the theoretical foundation of Solow's Growth Model (1956) and the empirical model developed by Osei et al. (2024), which examined the impact of climate finance on industrial diversification. Adapting their framework to align with the objectives of this study, the model was refined to assess the impact of climate finance, measured through Climate Equity Investment Funds, Climate Loans (Debt), and Climate Bilateral and Multilateral Grants/Aid, on industrial sector growth, proxied by industry value added (% of GDP), in selected Sub-Saharan African countries. The mathematical specification of the model applied in this paper is presented as follows:

$$INSG_{it} = \varphi_0 + \varphi_1 CEF_{it} + \varphi_2 CL_{it} + \varphi_3 CG_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Where;

INSG = Industrial sector growth

CEF = Climate Equity Investment Fund

CL = Climate Loan

CG = Climate (Bilateral and Multilateral) Grant/Aid

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φ_0 = Intercept or autonomous parameter estimate

$\varphi_1, \varphi_2, \varphi_3$ = Coefficients of Climate Equity Investment Fund, Climate Loan (Debt), Climate Bilateral and Multilateral Grant/Aid

μ_i = unobserved individual effects (or fixed effect error term, or unobserved heterogeneity)

ε_{it} = is the error term and $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$

Note: $i = 1, 2, ...N$ representing cross sections; $;t = 1, 2, ..., T$ representing time periods

To identify the most suitable panel estimation technique for this paper, the Hausman test was utilized as a diagnostic tool to evaluate whether the unobserved individual country effects were correlated with the explanatory variables. The outcome of this test was instrumental in determining the appropriate model choice between fixed effects and random effects. Employing this method ensured that the parameter estimates remained both consistent and efficient when examining the impact of climate finance on industrial sector growth across the selected Sub-Saharan African countries. The mathematical formulation of the Hausman test applied in the analysis is presented as follows:

$$H = (\varphi_{RE} - \varphi_{FE})' \left[Var(\varphi_{RE}) - Var(\varphi_{RE})^{-1} \right] (\varphi_{RE} - \varphi_{FE}) \quad (2)$$

Where:

φ_{RE} = coefficient vector from the Random Effects model

φ_{FE} = coefficient vector from the Fixed Effects model

$Var(\varphi_{RE})$ = variance-covariance matrix of φ_{RE}

$Var(\varphi_{RE})$ = variance-covariance matrix of φ_{FE}

H = Hausman test statistic

Under the null hypothesis H_0 : the preferred model is Random Effects (no correlation between regressors and individual effects); Under the alternative hypothesis H_1 : the Fixed Effects model is more appropriate (correlation exists). If the computed H -statistic is significant (p-value < 0.05), the null hypothesis is rejected, and the Fixed Effects model is preferred.

The mathematical representation of the Fixed Effects (FE) model is specified as:

$$y_{it} = \alpha_i + \varphi x_{it} + \varepsilon_{it} \quad (3)$$

Where:

y_{it} = the dependent variable (e.g., industrial sector growth) for country i at time t

α_i = unobserved individual-specific effect (captures time-invariant heterogeneity across countries)

x_{it} = vector of independent variables (e.g., Climate Equity Investment Fund, Climate Loan (Debt), and Climate Bilateral and Multilateral Grant/Aid)

φ = vector of coefficients to be estimated

ε_{it} = error term

The Fixed Effects model assumes that α_i may be correlated with the regressors x_{it} and it controls for this by allowing each country to have its own intercept. This approach focuses on within-country variations over time and eliminates time-invariant omitted variable bias.

The mathematical representation of the Random Effects (RE) model is given as:

$$y_{it} = \alpha + \varphi x_{it} + u_i + \varepsilon_{it} \quad (4)$$

Where:

y_{it} = the dependent variable (e.g., industrial sector growth) for country i at time t

α = common intercept across all countries

x_{it} = vector of explanatory variables (e.g., Climate Equity Investment Fund, Climate Loan (Debt), and Climate Bilateral and Multilateral Grant/Aid)

φ = vector of coefficients to be estimated

u_i = unobserved country-specific random effect (assumed to be uncorrelated with x_{it}

ε_{it} = idiosyncratic error term

The key assumption in the Random Effects model is that the unobserved effect u_i is uncorrelated with the regressors x_{it}. This allows the model to exploit both within- and between-country variations, making it more efficient than the Fixed Effects model when the assumption holds.

RESULTS AND DISCUSSION

Descriptive Statistics Results

Descriptive statistics provide a foundational understanding of the distribution, central tendency, and variability of data used in empirical analysis. In this study, descriptive statistics were used to summarize and interpret the behaviour of the key variables: Industrial Sector Growth (INSG), Climate Equity Investment Fund (CEF), Climate Loans (CL), and Climate Grants (CG). The summary statistics help to illustrate the nature and spread of the data across the selected Sub-Saharan African countries from 2009 to 2024, offering preliminary insights into the dynamics of climate finance and industrial sector growth.

Table 1: Summary Statistics Result

	INSG	CEF	CL	CG
Mean	22.14263	4525.709	266.3908	5549.350
Maximum	33.24000	42656.20	964.2100	12850.76
Minimum	9.440000	54.64000	1.350000	733.8300
Std. Dev.	4.931753	6365.511	216.2588	2891.614
Skewness	-0.66516	3.378873	0.970197	0.209776
Kurtosis	3.803067	18.34164	3.725356	2.594094
Jarque-Bera	8.048955	936.7772	14.30423	1.135942
Probability	0.017873	0.000000	0.000783	0.566674
Observations	80	80	80	80

Source: Researcher’s Computation Using EViews-12 (2025)

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From Table 1, the Industrial Sector Growth (INSG) variable, measured as industry value added (% of GDP), had a mean value of 22.14 percent, reflecting a moderate level of industrial contribution to GDP across the countries studied. The minimum observed value was 9.44 percent, while the maximum reached 33.24 percent, indicating a considerable disparity in industrial performance among countries. The standard deviation of 4.93 shows moderate variability around the mean. The negative skewness value (−0.665) suggests a leftward skew, meaning a greater number of countries experienced higher-than-average industrial growth. The kurtosis value of 3.80 indicates a distribution with slightly heavier tails than the normal distribution. The Jarque-Bera test probability of 0.017 indicates that INSG is not normally distributed at the 5% significance level, which may influence estimation techniques in subsequent regression analysis.

The Climate Equity Investment Fund (CEF) showed a mean of USD 4.53 billion, highlighting significant investment variation across the sample. With a maximum value of USD 42.66 billion and a minimum of just USD 54.64 million, the standard deviation of 6.37 billion indicates a high level of dispersion, reflecting the volatile nature of equity-based climate financing. The high positive skewness (3.38) and leptokurtic kurtosis (18.34) reveal an extreme right-tailed distribution, suggesting a few countries or years received disproportionately large equity inflows. The Jarque-Bera statistic strongly confirms non-normality with a p-value of 0.000, reinforcing the presence of outliers or irregular distributions in equity financing flows.

The Climate Loans (CL) variable had a mean value of USD 266.39 million, with a maximum of USD 964.21 million and a minimum of USD 1.35 million. The standard deviation of 216.26 million reflects moderate variability in loan disbursements across countries. A skewness of 0.97 indicates a rightward skew, showing that more countries had lower-than-average climate loan inflows. The kurtosis of 3.72, being close to 3, suggests the distribution is slightly peaked compared to a normal distribution. The Jarque-Bera p-value of 0.00078 confirms the variable is not normally distributed, suggesting that extreme loan values occurred in a few observations, likely tied to specific policy initiatives or infrastructure projects.

For Climate Grants (CG), the average inflow was USD 5.55 billion, with a minimum of USD 733.83 million and a maximum of USD 12.85 billion. The standard deviation of 2.89 billion shows substantial variation in grant allocations, likely reflecting differences in national absorptive capacity, donor priorities, or vulnerability levels. Skewness of 0.21 implies a nearly symmetric distribution, while a kurtosis of 2.59 suggests a distribution slightly flatter than normal. Unlike the other variables, the Jarque-Bera probability of 0.566 indicates that Climate Grants are normally distributed, meaning the values are evenly spread and free from extreme outliers or distortions.

Hausman Test

The Hausman test is a crucial econometric diagnostic used to determine the most appropriate panel estimation technique between the fixed effects and random effects models. It tests whether the unique errors (country-specific effects) are correlated with the explanatory variables. A statistically significant result indicates that the fixed effects model is preferable because it produces consistent estimates. The result of the test is shown in Table 2.

Table 2: Hausman Test Result

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	25.513387	3	0.0000

Source: Researcher's Computation Using EViews-12 (2025)

As shown in Table 2, the Hausman test produced a Chi-square statistic of 25.51 with 3 degrees of freedom and a p-value of 0.0000. Since the p-value is less than 0.05, the null hypothesis of no correlation between the regressors and the individual effects is rejected. This implies that the fixed effects model is more appropriate for this study.

Fixed Effect Regression Result

The paper established that there is a significant correlation between the regressors and the individual country effects, as indicated by the Hausman test result. Consequently, the analysis proceeds with the estimation using the Fixed Effects model. This method is appropriate because it focuses on within-country variations over the study period, allowing the model to control for time-invariant unobserved heterogeneity unique to each country. By accounting for these fixed country-specific characteristics, while assuming they are correlated with the explanatory variables, namely Climate Equity Investment Funds, Climate Loans (Debt), and Climate Grants, the Fixed Effects model provides a consistent and reliable framework for assessing the impact of climate finance on industrial sector growth, as shown in Table 3.

Table 3: Fixed Effect Regression Result

Dependent Variable: INDG

Method: Panel Least Square (Fixed effects)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
CEF	-0.2533	0.1764	-1.4363	0.1552
CL	0.4252	0.2057	2.0669	0.0423
CG	0.6352	0.2164	2.9353	0.0045
C	17.9340	1.3179	13.6081	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
Reliability Estimates				
Root MSE	3.0550	R-squared		0.6114
Mean dependent var	22.1426	Adjusted R-squared		0.5736
Hannan-Quinn criter.	5.3669	F-statistic		16.1845
Durbin-Watson stat	1.6725	Prob(F-statistic)		0.0000

Source: Researcher’s Computation Using EViews-12 (2025)

The coefficient for Climate Equity Investment Funds (CEF) is negative (−0.2533) and statistically insignificant, with a p-value of 0.1552. This suggests that, on average, increases in equity-based climate investments do not have a statistically significant impact on industrial sector growth within the observed timeframe.

In contrast, the coefficient for Climate Loans (CL) is positive (0.4252) and statistically significant at the 5 percent level (p = 0.0423). This implies that climate-related loans have had a meaningful and positive impact on industrial sector growth across the selected countries. These loans, often used to finance infrastructure, energy, and technology upgrades, appear to be more directly aligned with the types of capital investments that enhance industrial output.

The coefficient for Climate Grants (CG) is the largest (0.6352) and is statistically significant at the 1 percent level (p = 0.0045), indicating a strong and positive relationship between grant funding and industrial sector growth. Unlike equity or debt financing, grants do not impose repayment obligations and are often allocated to foundational investments such as infrastructure development, institutional reform, and capacity building.

The R-squared value of 0.6114 indicates that approximately 61.14% of the variation in industrial sector growth is explained by the independent variables, namely Climate Equity Investment Funds, Climate Loans, and Climate Grants. This suggests a moderately strong explanatory power, implying that the model captures a substantial proportion of the factors driving changes in industrial value added across the study period.

The Adjusted R-squared of 0.5736 further confirms the model’s robustness after adjusting for the number of predictors. This value accounts for degrees of freedom and remains relatively close to the unadjusted R-squared, reinforcing that the included variables meaningfully contribute to explaining industrial growth without overfitting.

The F-statistic value of 16.1845, coupled with a probability value of 0.0000, indicates that the overall model is statistically significant at the 1% level. This confirms that, collectively, the explanatory variables have a significant impact on the dependent variable.

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Lastly, the Durbin-Watson statistic of 1.6725 is within the acceptable range (typically between 1.5 and 2.5), suggesting that there is no strong evidence of autocorrelation in the residuals. This supports the reliability of the estimated coefficients and reinforces the validity of the fixed effects model used in the study. Overall, the reliability estimates affirm that the model is both statistically sound and well-specified for evaluating the influence of climate finance on industrial sector growth.

DISCUSSION OF FINDINGS

Findings from the study revealed that Climate Equity Investment Funds (CEF) had a negative and statistically insignificant impact on industrial sector growth in the selected Sub-Saharan African countries. This result suggests that although equity financing is theoretically expected to catalyse innovation and industrial expansion, its actual effectiveness remains limited in the region, likely due to insufficient scale, weak institutional capacity, and the concentration of such funds in a few large economies. The implication is that climate equity investments, in their current form, may not be reaching the productive industrial segments where their transformative potential is most needed. This outcome aligns with the findings of Twum et al. (2024), who observed that equity investments tend to have a threshold effect, only becoming impactful when annual flows exceed significant levels, often unattainable in lower-income economies. Similarly, Bai and Wang (2024) emphasized that equity flows are highly volatile and often biased toward sectors with clearer revenue models, sidelining foundational industrial activities that lack immediate returns. However, this finding diverges from the work of Zhang and Mbaye (2022), who found that equity investments had a statistically significant and positive impact on industrial output in middle-income African economies, suggesting that national income level and absorptive capacity are critical to how equity financing influences industrial performance.

Conversely, the study showed that Climate Loans (CL) had a positive and statistically significant impact on industrial sector growth across the sample countries. This result implies that concessional and market-rate climate loans have played a meaningful role in enhancing industrial capacity through financing of sustainable infrastructure, energy efficiency upgrades, and clean technology adoption. The positive impact supports the argument that well-structured debt instruments can provide the long-term capital required for industrial modernization in emerging economies. This finding is consistent with Asante and Mensah (2024), who reported that concessional climate loans significantly improved manufacturing productivity in Sub-Saharan Africa by financing large-scale industrial upgrades. Similarly, Kumi and Boateng (2024) found that climate loan inflows into Ghana contributed to growth in industrial value added, particularly in energy-intensive manufacturing sectors. However, while loans were found to be effective, Sossa (2024) cautioned that their success is often contingent upon sound debt management frameworks and project execution capacity, which may not be uniform across the region.

The study also found that Climate Grants (CG) had the strongest and most statistically significant positive effect on industrial sector growth among the climate finance components. This suggests that grant-based financing, being non-repayable, has served as a critical enabler of industrial growth by supporting climate-resilient infrastructure, capacity building, and institutional reforms that create a conducive environment for industrial activities. The implication is that grants, although often used for adaptation or resilience projects, have indirect but substantial spillover effects on the industrial sector. This aligns with the findings of Nakamura et al. (2024), who observed that climate adaptation grants significantly contributed to green employment and industrial development in small island economies by improving foundational infrastructure. Similarly, Diallo and Camara (2023) noted that in francophone West Africa, climate grants had a strong effect on industrial energy efficiency and long-term industrial capacity. Nonetheless, while this study confirms the importance of grants, Rodriguez and Kim (2024) argued that the effectiveness of grants also depends heavily on the presence of transparent governance and institutional frameworks to ensure proper allocation and utilization of funds. Hence, the positive result for grants in this study may reflect the effectiveness of donor coordination or country-specific institutional strengths.

CONCLUSION AND RECOMMENDATIONS

Based on the findings and analysis presented, this study concludes that climate financing plays a critical but differentiated role in influencing industrial sector growth across selected Sub-Saharan African countries. The fixed effects regression results, supported by rigorous diagnostic tests, confirm that not all forms of climate finance contribute equally to industrial development. Specifically, climate loans and grants emerged as statistically significant and positively associated with industrial sector growth, while climate equity investments showed a negative but insignificant effect within the observed period. These findings reflect the structural realities of many African economies, where concessional loans and grant-based financing remain more accessible, better aligned with public-sector-led industrial projects, and more effective in bridging infrastructure and institutional gaps necessary for industrial transformation.

The significance of climate loans suggests that access to long-term, low-interest capital has been instrumental in financing industrial infrastructure and clean energy transitions, essential components of modern industrial systems. Similarly, the effectiveness of climate grants highlights the importance of non-repayable support in enabling foundational reforms, technology transfer, and capacity-building, all of which contribute to a more resilient industrial base. However, the limited impact of equity investments highlights persistent challenges related to investment scale, project bankability, and private sector readiness.

In light of the study's findings, specific and actionable recommendations are warranted to enhance the effectiveness of climate finance in fostering industrial sector growth across Sub-Saharan Africa.

1. First, the insignificant impact of Climate Equity Investment Funds suggests a need for scaling up and restructuring these investments to better suit the realities of local industrial sectors. Governments, in collaboration with institutions such as the African Development Bank (AfDB) and the Green Climate Fund (GCF), should establish blended finance facilities that de-risk equity investments and attract private sector participation in manufacturing, construction, and green infrastructure. National development banks, such as Nigeria's Bank of Industry (BoI) or Kenya's Industrial and Commercial Development Corporation (ICDC), should also design instruments that offer co-financing and technical support to make equity projects more viable.
2. The significant positive impact of Climate Loans points to the importance of expanding access to concessional debt while ensuring debt sustainability. To this end, ministries of finance and planning across Sub-Saharan African countries should work with international financial institutions such as the World Bank, the International Monetary Fund (IMF), and the Climate Investment Funds (CIF) to negotiate favourable loan terms specifically targeted at industrial upgrades. These loans should prioritize renewable energy for manufacturing, industrial parks, and sustainable logistics infrastructure. Furthermore, regional institutions like the African Union Development Agency (AUDA-NEPAD) should provide technical assistance to help countries integrate industrial development into national climate financing frameworks and ensure effective implementation of loan-funded projects.
3. Given the strong and significant impact of Climate Grants on industrial growth, it is crucial to enhance the capacity of national institutions to attract and manage such funds effectively. National climate finance units within ministries of environment and industry should be strengthened to coordinate proposals and reporting requirements, ensuring alignment with industrial priorities. Institutions such as the United Nations Industrial Development Organization (UNIDO) and the United Nations Economic Commission for Africa (UNECA) should provide capacity-building and policy advisory services to help countries design industrial policies that are grant-attractive and climate-aligned. Donor agencies, including the European Union, USAID, and the German Development Cooperation (GIZ), should tailor their grant support to include components that enable technology transfer, industrial training, and supply chain development in recipient countries.

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APPENDIX

Data Presentation

Table A: Data Presentation

Year	Country	Climate Equity Investment Fund ($m)	Climate Loan (Debt, $m)	Climate Bilateral and Multilateral Grant/Aid ($m)	Industry (value added (% of GDP)
2009	Ethiopia	929.57	7.09	8477.29	9.68
2010	Ethiopia	419.06	162.42	5738.56	9.44
2011	Ethiopia	616.76	34.39	5377.3	9.66
2012	Ethiopia	115.81	100.89	7161.25	9.48
2013	Ethiopia	183.33	21.11	5126.48	10.94
2014	Ethiopia	206.27	379.52	5803.81	13.47
2015	Ethiopia	2482.78	209.48	8013.8	16.3
2016	Ethiopia	2804.32	52.4	7407.6	21.93
2017	Ethiopia	1412.7	917.47	9953.26	23.58
2018	Ethiopia	1099.73	16.61	9323.62	27.31
2019	Ethiopia	464.84	182.01	8071.51	24.82
2020	Ethiopia	124.72	461.86	10609.82	23.1
2021	Ethiopia	1014.66	454.22	8524.93	21.85
2022	Ethiopia	906.04	123.75	12670.68	22.72
2023	Ethiopia	1633.14	343.51	10520.8	24.48
2024	Ethiopia	1285.42	298.67	11247.35	25.73
2009	Nigeria	7941.58	56.8	5368.23	21.24
2010	Nigeria	1184.19	157.76	2039.16	25.32
2011	Nigeria	6144.06	138.2	2706.77	28.28
2012	Nigeria	11996.13	331.14	5311.22	27.07
2013	Nigeria	3258.11	586.77	4120.68	25.74
2014	Nigeria	7435.51	505.17	4896.75	24.64
2015	Nigeria	42656.2	19.83	4904.85	20.16
2016	Nigeria	23494.3	246.48	4416	18.17
2017	Nigeria	9557.32	137.23	6619.48	22.32
2018	Nigeria	1652.82	181.5	8910.78	25.73
2019	Nigeria	7436.99	337.09	3079.01	27.38
2020	Nigeria	57.13	734.12	12850.76	28.22
2021	Nigeria	4172.69	964.21	7853.48	31.41
2022	Nigeria	3013.97	557.32	5221.67	30.78
2023	Nigeria	481.27	559.26	6922.59	32.58
2024	Nigeria	2134.85	687.94	8456.73	33.24
2009	South Africa	5263.66	110.22	4513.48	25.74
2010	South Africa	10836.76	473.88	3490.27	25.3
2011	South Africa	16657.24	7.92	5096.97	24.84
2012	South Africa	5284.86	308.21	5930.94	24.47
2013	South Africa	8554.21	99.74	7282.39	24.55
2014	South Africa	12937.3	215.99	6868.08	24.31
2015	South Africa	8722.42	498.52	6878.85	23.73
2016	South Africa	8970.57	515.95	7528.46	23.78
2017	South Africa	9571.13	654.19	6417.49	23.61
2018	South Africa	10553.83	243.36	6056.86	23.54
2019	South Africa	10090.73	178.19	6513.93	23.62
2020	South Africa	4735.42	282.85	7756.14	23.34

2021	South Africa	5565.56	498.05	7094.66	24.87
2022	South Africa	969.63	386.53	8236.15	24.93
2023	South Africa	4992.78	249.33	6833.31	24.62
2024	South Africa	6847.92	421.67	7485.29	24.89
2009	Kenya	2223.84	40.02	4471.89	18.39
2010	Kenya	54.64	105.5	4266.05	18.57
2011	Kenya	1494.1	28.67	4922.02	19.66
2012	Kenya	1267.99	254.69	7545.43	19.26
2013	Kenya	3685.74	89.7	4124.54	19.08
2014	Kenya	1528.47	309.28	4332.01	19.04
2015	Kenya	478.24	257.14	5807.72	18.89
2016	Kenya	649.41	230.14	4447.7	18.16
2017	Kenya	1782.66	387.65	6078.17	17.5
2018	Kenya	1111.93	527.38	3335.74	17.31
2019	Kenya	1738.77	317.86	4160.85	16.93
2020	Kenya	387.72	435.21	8520.51	17.4
2021	Kenya	523.51	446.51	5560.16	17.15
2022	Kenya	602.32	208.34	5205.9	17.53
2023	Kenya	690.35	88.5	8762.84	16.86
2024	Kenya	425.68	267.42	6834.57	16.45
2009	Senegal	2846.37	1.35	1551.1	22
2010	Senegal	662.47	3.9	1101.2	21.78
2011	Senegal	2788.91	28.02	869	23.31
2012	Senegal	4413.96	52.79	937.57	23.11
2013	Senegal	1858.83	28.93	1401.49	24.29
2014	Senegal	3269.95	29.91	733.83	23.15
2015	Senegal	20110.77	95.8	1452.45	23.6
2016	Senegal	11871.6	127.33	821.18	23.34
2017	Senegal	3895.62	110.25	1967.01	23.28
2018	Senegal	1509.05	439.87	2185.58	24.01
2019	Senegal	3229.96	183.81	1471.75	23.57
2020	Senegal	1988.27	165.54	1413.67	23.21
2021	Senegal	799.68	41.23	1786.04	23.91
2022	Senegal	1478.18	188.47	2072.52	24.79
2023	Senegal	1669.48	423.49	2174.16	24.3
2024	Senegal	2147.93	285.74	1943.82	24.67

Sources: OECD. (2024). Development Assistance Committee (DAC), Climate Policy Initiative (CPI), Green Climate Fund, World Bank Climate Investment Funds. https://www.oecd.org/climate-change/finance-usd-100-billion-goal/ World Bank. (2025). World Development Indicators (WDI). Retrieved from https://databank.worldbank.org/source/world-development-indicators