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Climate change and income inequality in Sub-Saharan African countries

Naftaly Mose[1+]
Seth Acquah Boateng[2]
Michael Provide Fumey[3]
Stoyan Tanchev[4]

[1]*University of Eldoret, Eldoret, Kenya.*
[1]*Email: brilliantcoke@gmail.com*
[2,3]*Northwestern Polytechnical University, Xi'an, China.*
[2]*Email: fumeymichael3@gmail.com*
[3]*Email: sethboatengacquah36@gmail.co*
[4]*South-West University "Neofit Rilski", Blagoevgrad, Bulgaria.*
[4]*Email: stoyan_tanchev@swu.bg*

(+ Corresponding author)

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ABSTRACT

The potential for a feedback relationship between climate change and income inequality has become a concern in sub-Saharan African (SSA) countries due to its significant environmental and socio-economic impacts. This study aims to inform policymakers on ways to address inequality and climate resilience in the region simultaneously. It examines the relationship between climate change and income inequality in SSA countries, focusing on Kenya, Tanzania, and Uganda, by analyzing data from these three countries between 2009 and 2023. The Dumitrescu and Hurlin adaptation of the Granger causality test and pooled ordinary least squares research techniques were used in the analysis. The results of the pooled ordinary least squares model reveal that rising income inequality has a positive impact on climate change. Conversely, climate change exhibits a positive impact on income inequality. The Dumitrescu-Hurlin causality evidence indicates a strong, bidirectional relationship between climate change and income inequality in the three countries. This implies that the lagged value of climate change explains the variation in income inequality, with a feedback response where the lagged value of income inequality is instrumental in predicting climate change. The study suggests implementing inclusive economic growth and development policies aligned with climate mitigation measures and adaptation objectives.

Contribution/ Originality: The present study contributes to the increasingly rich literature on the two-way relationships that income inequality and climate change share in selected African countries. It adopts a dual model to establish how climate change affects income distribution and how, in turn, income inequality invariably influences climate change. Using poverty, population growth, carbon emissions, and GDP, the study provides a comprehensive enumeration of socio-environmental dynamics. Based on its findings, the study aims to inform policymakers on ways to address inequality and enhance climate resilience in the region simultaneously.

1. INTRODUCTION

The proliferation and acceleration of global climate change and increasing inequalities represent arguably the principal challenges in the development of the 21st century (Benton, Morisetti, & Brown, 2023; Natarajan, Newsham, Rigg, & Suhardiman, 2022), forming an intricate and synergistic feedback loop destructive to global stability and sustainable development (Olorogun, 2024; Tomala, Mierzejewski, Urbaniec, & Martinez, 2021). According to the World Inequality Report 2022, the wealthiest top 10% of the global population holds 76% of the total wealth; the poorest half owns only 2%. Additionally, between 1990 and 2015, the wealthiest 1% of the global population produced more than twice the carbon emissions of the bottom 50%. The IPCC also reported that from 1850-1900 to 2011-2020, there was an increase of 1.1°C in global surface temperature (Bruckner, Hubacek, Shan, Zhong, & Feng, 2022; Nielsen, Nicholas, Creutzig, Dietz, & Stern, 2021; Wang & Li, 2021). With the Swiss Re Institute forecasting a possible 11-14% global GDP decline by 2050 due to temperature rises of 2.6°C, the financial consequences of such a correlation are significant. In contrast to developing countries, these nations could experience GDP losses of up to 20% (Arora & Mishra, 2021; Wang, Li, Li, & Jiang, 2022). The World Bank reports that climate change could push 132 million people into extreme poverty within the next 13 years (WDI., 2024). This also establishes a vicious cycle in which wealth inequality amplifies vulnerability to the climate crisis, thereby widening the existing rich-poor gap (Liu, Liu, Afthanorhan, & Hao, 2024).

Examples of severe impacts from climate change and associated inequalities are observed across Sub-Saharan Africa (Dingru, Onifade, Ramzan, & Al-Faryan, 2023; Nyiwul, 2021). This is, even though it is projected at 3 percent only of global carbon emissions, according to the (WDI, 2023). It is a region with severe climate impacts, with the United Nations Economic Commission for Africa revealing that from 1970 until 2019, droughts and floods alone caused more than $70 billion in economic losses, and income inequality remains high (Agwanda, Dagba, Opoku, Amankwa, & Nyadera, 2021). According to the African Development Bank, seven of the ten most unequal countries in the world are in the SSA region, where their average Gini coefficient exceeds 0.45, which is much higher than in other developing regions (African Development Bank, 2019). Such forces converge to create dire consequences for the most vulnerable populations in Sub-Saharan Africa (Gamette, Odhiambo, & Asongu, 2024; Zheng et al., 2023). The World Food Programme reports a 67% increase in food insecurity associated with climate events since 2015; this is primarily an urban phenomenon and mainly affects low-income households (Ogwu, Izah, Ntuli, & Odubo, 2024). The IMF's Regional Economic Outlook estimates that climate shocks in SSA lower per capita GDP by 1% in the year of occurrence but continue to impact subsequent years. Their contribution is far more significant for the poorest quintile of the population. At the same time, adaptive capacity is further limited by the fact that, according to the World Bank, not even 31% of households in SSA have access to the necessary essential financial services for climate resilience, compared to an average of 69% globally (Ahmad & Afzal, 2021). Therefore, this study establishes a two-way association between income inequality and climate change in some selected SSA countries while simultaneously utilizing the equations to inform integrated policy development strategies for the region.

Economic growth causes considerable poverty reduction through carbon emissions and income (Duong & Flaherty, 2023). When growth is met with low income, it leads to emissions from carbon and poorer countries (Fumey, Sackitey, & Wiredu, 2024; Li, Sampene, Agyeman, Brenya, & Wiredu, 2022). When growth is high and wealthy, only income inequality causes the issue (Duong & Flaherty, 2023; Min, Soergel, Kikstra, Koch, & van Ruijven, 2024). Feedback mechanisms are formed by income inequality and climate change; climate change aggravates the disparity, which worsens the effects of climate change (Min et al., 2024; Ogbeide-Osaretin, Orhewere, Ebhote, Akhor, & Imide, 2022). The U-shaped hypothesis appears to represent this relationship, where the extremes—low and high inequality affect climate change differently. Therefore, addressing income inequality through employment, education, and an efficient energy supply can reduce the adverse effects of climate change and support economic growth (Ogbeide-Osaretin et al., 2022).

Most contemporary climate change and income inequality studies do not examine these variables in their intersections or contexts (Ahmad, Raid, Alzyadat, & Alhawal, 2023; Gamette et al., 2024; Jonathan Gimba, Seraj, & Ozdeser, 2021; Yasin, Hasan, & Anwar, 2024; Yeboah, Gatsi, Appiah, & Fumey, 2024; Zheng, Wan, & Huang, 2023). There has been some research examining the socioeconomic effects of climate change; however, very few have attempted to observe the two-way relationship between climate change and income inequality, especially in SSA, where greenhouse gas emissions are primarily associated with vulnerability to the risks posed by climate change. This gap in research, particularly on how income inequality worsens climate change impacts and vice versa, has motivated this study. Understanding these dynamics for policy intervention in the region, which continuously grapples with poverty, population growth, and carbon emissions, is essential. The current research is grounded on the following objectives: first, to determine the impact of climate change on income inequality in SSA, and second, to ascertain the effect of income disparities on climate change in SSA. The present study contributes to the increasingly rich literature on the two-way relationships between income inequality and climate change in selected SSA countries. It employs a dual model to establish how climate change affects income distribution and how, in return, income inequality invariably influences climate change. Using poverty, population growth, carbon emissions, and GDP, the study includes a comprehensive analysis of socio-environmental dynamics. Based on its findings, the study aims to inform policymakers on ways to address inequality and climate resilience in the region simultaneously.

Apart from the introduction, the remainder of the work is systematized: Section two summarizes the theoretical underpinning and relevant literary works on the research topic. Section three provides the data and assessment techniques. Section four presents the empirical findings and discussion. The conclusion, implications, limitations, and future investigations of the study are included in section five.

2. LITERATURE REVIEW

2.1. Theoretical Framework

The theoretical approach combines the Environmental Kuznets Curve (EKC) theory with environmental justice principles to explore the complex link between income inequality and climate change in East Africa (Grossman & Krueger, 1991; Hasan, Wieloch, Ali, Zikovic, & Uddin, 2023). Under the EKC hypothesis, there is a reverse U-shaped correlation between economic development and environmental deterioration (Rahman, Lubis, RGP, Yuandita, & Khoirudin, 2023). With increasing income during initial development, there is also a rise in ecological harm due to industrial expansion and the use of natural resources. Nevertheless, beyond a certain point in time, environmental health begins to improve as economies expand and nature is conserved (Rahman et al., 2023). The theory explains how patterns of economic growth in Kenya, Uganda, and Tanzania influence their environmental outcomes and income distribution. Environmental justice theory expands on this by examining the equitable distribution of environmental impacts across different social groups (Siegfried, 2024). The theory asserts that societal ecological issues and gains are unequal, and vulnerable groups suffer more environmental harm (Islam, 2024). In East Africa, it is observed that the combination of climate threats and prevailing social inequalities creates a cycle of environmental damage and increasing inequality. The two concepts describe how economic expansion influences the environment, how it is experienced across various income groups, and how it is connected to social inequality. The concepts provide evidence for existing studies that indicate multifaceted relationships between social inequality and climate change (Dias, 2024), especially in developing economies where social and environmental issues tend to be interconnected. The method indicates a need to enact policies that concurrently conserve the environment and promote social equality to prevent further ecological harm and inequality.

2.2. Review of Related Studies

A substantial body of recent scholarly work has presented compelling evidence that climate change significantly impacts income inequality in various contexts. The evidence shows that climate change differentially affects low-income groups, widening existing economic gaps domestically and globally (Dang, Hallegatte, & Trinh, 2024; Méjean et al., 2024). The mechanisms through which climate change influences income inequality are multifaceted and varied. Temperature variations, in particular, have serious consequences for current economic status and chronic poverty, especially in low-income economies (Dang et al., 2024). In SSA, increased exposure to climate change is positively associated with widening income inequality, moderated by per capita GDP, demographic patterns, and agricultural yields (Bitoto, Nchinda Mbognou, & Amougou Manga, 2025). A cross-country comparative analysis indicates that the effects of climate change differ widely based on initial per capita income levels. An in-depth study of 110 countries showed that climate change aggravates increasing income inequality to a much greater extent in low-income economies, posing a troubling moral question: why do more prosperous nations carry a disproportionate burden of climate change compared to their poorer counterparts (Wildowicz-Szumarska & Owsiak, 2024). The increasing temperatures significantly impact a country's vulnerable segments, even when their adaptation capability is considered, whereas more affluent households face relatively low consequences (Gilli, Calcaterra, Emmerling, & Granella, 2024).

Institutional quality is a key intermediary between inequality and climate change. Analyses in Asia indicate that although climate variables, such as precipitation and temperature, widen income gaps, better institutional quality can help close these gaps and mitigate the effects of climate change (Huynh & Hoang, 2024). This highlights the urgent need for institutional reforms to address the linked challenges of inequality and climate change. The impact of climate change on distribution manifests through several channels. Fried (2024) explains that temperature changes affect household welfare differently, varying across groups regarding energy use and adaptation requirements. Global analysis, using estimates of climate and population on a grid, shows a statistically significant link between increases in temperatures and a range of aspects of distribution, such as distribution of income, concentration of wealth, and gaps in life expectancy (Castells-Quintana & McDermott, 2024). Sarkar (2024) finds that gender is a key intermediary between climate variables and inequality, determining employment patterns and social infrastructure access. The evidence presented highlights the complex interaction between climate change and inequality, emphasizing the need for a wide range of policy interventions that consider social and environmental aspects. Generally, this evidence portfolio indicates that climate change exacerbates existing inequalities, affecting them differently across geographic, institutional, and socioeconomic contexts. The evidence underscores the importance of integrated policy approaches that address climate change adaptation alongside efforts to reduce inequality.

Furthermore, recent studies indicate a dynamic two-way link between carbon emissions and inequality, in that each one supports the other's resource utilization and emissions (Huang, 2024). The results indicate that carbon emissions are connected to inequality in multiple ways, varying across emission types over time. Studies on carbon inequality reveal significant discrepancies in emissions among different social and economic groups. From 2005 to 2015, carbon footprints in 43 large economies in high-income countries were found to be low; however, these economies also exhibited high carbon inequality, while low-income economies experienced increasing emissions along with varying patterns of inequality (Zheng et al., 2023).

In developing economies, high-income groups saw their carbon footprints dramatically escalate, eventually overtaking developed economies in 2014. In the United States, evidence of emission inequality is unambiguous and highly polarized across racial and economic groups. The studies indicate that a significant 40% of total US emissions are attributable to the wealthiest 10% of households, while the richest 1% emit between 38% and 43% of total emissions (Starr, Nicolson, Ash, Markowitz, & Moran, 2023). In 2019, the wealthiest 0.1% of households emitted a whopping 57 times more carbon than the bottom 10% (Starr et al., 2023).

A comprehensive review of 1990 to 2019 shows that the bottom 50% of the global population emitted just 12% of total emissions, while the richest 10% emitted 48%. Significantly, 63% of the worldwide inequality in per-capita emissions is now attributable to high- and low-emitting individuals within particular countries, rather than between countries (Chancel, 2022).

Analysis of 43 economies using the Multi-Regional Input-Output model shows that a decline in income inequality, measured using the Gini coefficient, significantly enables the decoupling of carbon emissions from economic growth, particularly in more prosperous economies (Dorn, Maxand, & Kneib, 2024). The link between inequality and emissions is nonlinear. A range of variables, such as consumption patterns, energy use, economic configurations, and institutions of governance, condition it. Analysis of 109 countries between 1960 and 2019 reveals that more affluent countries, though farther from sustainability metrics, hold the maximum potential to become more sustainable using a set of targeted social and ecological actions (Dorn et al., 2024).

3. DATA AND RESEARCH METHODS

3.1. Data Type and Source

Sub-Saharan Africa (SSA) coverage includes 49 of Africa's 55 countries and spans four regions. West Africa, which extends from Senegal to Chad; Central Africa, from Cameroon to the Democratic Republic of the Congo; East Africa, from Sudan to Tanzania; and Southern Africa, from Angola to South Africa, are the four primary regions comprising SSA. The study conducts panel analysis for three SSA countries with similar economic environments and member states of the East African Community: Kenya, Tanzania, and Uganda. Based on the availability of secondary data, the estimation covers panel data from 2009 to 2023 for these three countries. The variables considered in the research include income inequality (GINI), climate change (T), economic growth (GDP), and population growth (POP). Data for temperature was acquired from the Climate Change Knowledge Portal (World Bank, 2021) while the Gini index, per capita GDP, and population growth were drawn from the World Development Indicators (WDI, 2023). In line with empirical and theoretical literature, the significant determinants of climate change are the earth's temperature and rainfall precipitation. In this study, climate change denotes temperature change, while income inequality is quantified by the Gini coefficient (gross and net) due to its simplicity and acceptability. The model consists of relevant control variables for income inequality and climate change, including economic growth and population growth. For detailed variable information, measures, and expected prior signs, refer to Table 1. Table 1 shows the specific measurement and expected signs of study variables.

Table 1. Description of variables.

Variable	Description	Data source	Prior sign
Income inequality (GINI)	Gini index (%)	WDI	Not defined
Climate change (T)	Mean surface air temperature (^{O}C)	CCKP	Positive (Huynh & Hoang, 2024)
Population growth (POP)	Population growth (%)	WDI	Positive (Dorn et al., 2024)
Industrial structure (IND)	Industry, value added (% of GDP)	WDI	Positive (Chancel, 2022)
Economic growth (GDP)	Per capita GDP	WDI	Negative (Hasan et al., 2023)

3.2. Model Specification

The regression function is based on the endogenous growth model (Barro, 1990). We incorporate two-panel estimation regression models to capture the feedback effect: (i) a model for income inequality as the dependent variable and (ii) a model for climate change as the dependent variable. The general income inequality and climate change models (Equations 1 and 2).

$$\mathrm{GINI} = f(\mathrm{T}, \mathrm{IND}, \mathrm{GDP}, \mathrm{POP}) \quad (1)$$

$$\mathrm{T} = f(\mathrm{GINI}, \mathrm{IND}, \mathrm{GDP}, \mathrm{POP}) \quad (2)$$

Further, the basic linear regression model for income inequality and climate change has the following structure (Equations 3 and 4). Equation 3 presents our baseline estimation model, where the dependent variable is the Gini index as the proxy of income inequality. In contrast, in Equation 4, the dependent variable is temperature as the proxy for climate change.

$$\mathrm{GINI}_{it} = \alpha + \delta_1 \mathrm{T}_{it} + \delta_2 \mathrm{IND}_{i,t} + \delta_3 \mathrm{GDP}_{it} + \delta_4 \mathrm{POP}_{it} + \varepsilon_{it} \quad (3)$$

$$\mathrm{T}_{it} = \alpha + \delta_1 \mathrm{GINI}_{it} + \delta_2 \mathrm{IND}_{i,t} + \delta_3 \mathrm{GDP}_{it} + \delta_4 \mathrm{POP}_{it} + \varepsilon_{it} \quad (4)$$

Where

GINI = Gini Index a measure of income inequality.

T = Temperature a measure of climate change.

POP = Population growth rate.

GDP = Real Gross Domestic Product per capita. This was used to capture the level of economic development.

IND = industrial structure.

where δ represent the elasticities of the variables in the regression model. t represents the time dimension, i represents the country dimension, and ε is the error term.

3.3. Estimation Methods

This study employs descriptive, correlation, and regression analyses on panel data to investigate the effect of climate change on income inequality and vice versa in SSA countries. To ensure the accuracy of the estimated results, the study first examines the stationarity characteristics of each variable using the Levin-Lin-Chu unit root test. Next, the study performs a cointegration test using the Kao cointegration test to assess the long-run relationships among the variables. The study utilizes a pooled ordinary least squares (POLS) estimation approach to estimate the panel regression model based on a sample of three countries from 2009 to 2023. Causality hypotheses are tested using the Dumitrescu and Hurlin adaptation of the Granger causality test to examine the linkage between variables (Dumitrescu & Hurlin, 2012; Granger, 1988). The study chose the D-H panel causality procedure over the stacked (ordinary) pairwise causality test because it considers heterogeneity across cross-sections. This method effectively addresses the issue of endogeneity, which is commonly encountered in panel data analysis but often overlooked in empirical research (Dumitrescu & Hurlin, 2012). Finally, post-diagnostic tests such as the normality test (Jarque-Bera test), autocorrelation tests (Durbin-Watson test and Breusch-Godfrey test), heteroscedasticity test (Breusch-Pagan test), and cross-sectional dependence test (Pesaran CD) are performed to support the quality of the model and findings.

4. FINDINGS AND DISCUSSION

4.1. Results of Descriptive Statistics and Correlation Matrix

The descriptive statistics for the variables GINI, T, GDP, IND, and POP convey heterogeneity because of the variable values in Table 2. The Gini index measures income inequality with a mean of 41.21, indicating a moderately high level of inequality. Temperature (T) has a mean of 23.80°C, with a slight positive skew due to some extreme higher values. GDP per capita (GDP) shows considerable variation, reflected in a mean of 2.82 with a large spread, as some countries have negative minimum values in this sample. Industrial structure (IND) has a mean value of 23.52%, which is prone to high variation, with a standard deviation of 4.06, indicating a highly variable contribution of industry to GDP. Population growth (POP) has a mean of approximately 2.80% and exhibits moderate dispersion, with a relatively low negative skewness. The low Jarque-Bera values for GINI and POP suggest possible normality, in contrast to the apparent non-normality of GDP and IND, as some extreme observations seem to dominate the performances.

Table 2. Summary statistics for SSA countries.

Variables	GINI	T	GDP	IND	POP
Mean	41.207	23.803	2.823	23.517	2.796
Median	41.000	23.190	2.951	25.399	2.931
Maximum	48.900	25.540	5.565	28.671	3.490
Minimum	32.910	22.720	-2.210	16.860	1.900
Std. dev.	3.483	1.030	1.111	4.063	0.459
Skewness	-0.082	0.607	-2.001	-0.534	-0.601
Kurtosis	2.774	1.566	11.795	1.583	2.291
Jarque-Bera	0.145	6.626	175.098	5.905	3.651
Probability	0.929	0.036	0.000	0.052	0.161
Sum	1854.350	1071.140	127.052	1058.276	125.820
Sum sq. dev.	533.870	46.758	54.397	726.432	9.309
Observations	45	45	45	45	45

The correlations reveal interesting relationships between variables, as shown in Table 3. GINI and T show a weak positive correlation (0.24), with the rather suggestive interpretation that higher temperatures are somewhat associated with increased income inequality. A significantly negative correlation (T and GDP, -0.29) suggests that higher temperatures could be linked to lower economic growth in that particular region. Another robust negative correlation (-0.91) between T and IND strongly indicates that rising temperatures are associated with diminishing industrial activity due to climate impacts on industrial sectors. The positive correlation between IND and POP (0.81) indicates that countries with more industrial activity also experience higher population growth. GINI has a very low negative correlation with GDP (-0.08), which means income inequality is not a strong predictor of growth in this context. In summary, the matrix indicates a mixed set of relationships, with some variables showing strong correlations and others demonstrating moderate or weak associations.

Table 3. Correlation of the variables.

Variables	GINI	T	GDP	IND	POP
GINI	1				
T	0.239	1			
GDP	-0.084	-0.289	1		
IND	0.004	-0.906	0.265	1	
POP	0.040	-0.745	0.253	0.807	1

4.2. Results for Econometric Analysis

4.2.1. Results of Stationarity Test

According to the results of the Levin-Lin-Chu (LLC) unit root test in Table 4, climate change (T) and population growth (POP) are non-stationary at levels. In contrast, income inequality (GINI), economic growth (GDP), and industrial structure (IND) are stationary at levels. All variables become stationary after the first differencing, indicating that the series for T and POP are integrated of order 1 (I(1)), while GINI, GDP, and IND are stationary at level (I(0)).

Table 4. Panel unit root tests results.

Variables	Levin-Lin-Chu at level		Conclusion	LLC at first difference		Decision
	t-statistics	P-value		t-statistics	p-value	
GINI	-12.163	0.000	I (1)	-	-	-
T	14.912	1.000	I (0)	-21.374	0.000	I(0)
GDP	-4.731	0.000	I (1)	-	-	-
IND	-12.704	0.000	I (0)	-	-	-
POP	2.901	0.998	I (1)	-62.527	0.000	I(0)

Based on Levin Lin Chu's unit root test, climate change and population growth are non-stationary, while income inequality, economic development, and industrial structure are stationary at the level.

4.2.2. Results of Cointegration Test

With the Kao Cointegration test (Kao, Chiang, & Chen, 1999), income inequality and climate change findings reveal that the independent variables introduced do not share a long-run relationship with them. Observed values in Table 5 denote that the ADF t-statistic for income inequality is 0.93 while the p-value is 0.1753, inferring no cointegration. Likewise, Table 6 indicates that the ADF t-statistic for climate change is -0.30, with a p-value of 0.3816, which does not reject the null hypothesis of no cointegration. Insignificant p-values in the two tests imply that the series lack long-term relationships in their respective regression models.

Table 5. Results of the Kao cointegration test for the income inequality model.

ADF	t-statistics	Prob.
	0.933	0.175
Residual variance	22.672	
HAC variance	3.582	

Note: Null hypothesis: No cointegration.

Table 6. Result of Kao Cointegration test for climate change model.

ADF	t-statistics	Prob.
	-0.301	0.381
Residual variance	0.330	
HAC variance	0.0454	

Note: Null hypothesis: No cointegration.

The P-value is insignificant, implying that the series has no long-term relationship in either regression model.

4.2.3. Estimation Results of the Econometric Model

4.2.3.1. Impact of Climate Change on Income Inequality in SSA

The panel estimation results in Table 7 highlight some important intersections between climate change and income inequality. The analysis clarifies that, in general, rising temperature (T) as an indicator of climate change is significantly positively related to the Gini index-based income inequality. It indicates that the adverse impacts of climate change, such as environmental damage or resource scarcity, are likely to have a greater impact on low-income groups, thereby widening the income gap. This aligns with previous research showing that climate change differentially affects low-income groups, increasing existing economic disparities both domestically and globally (Dang et al., 2024; Méjean et al., 2024). In SSA, increased exposure to climate change is positively associated with widening income inequality, moderated by per capita GDP, demographic patterns, and agricultural yields (Bitoto et al., 2025). The result warrants attention to policies that address both climate change and social inequality simultaneously. Additionally, the association between income inequality and GDP indicates that increased economic growth, as measured by GDP, tends to reduce income inequality. However, the evidence is statistically insignificant in this model, which means that although economic growth is expected to decrease inequality, the reasons behind this are unclear, and some countries may obscure these effects. With increasing income during initial development, there is also a rise in ecological harm due to industrial expansion and the utilization of natural resources. Nevertheless, beyond a certain point in time, environmental health begins to improve as economies expand and natural resources are conserved (Rahman et al., 2023). Therefore, it is most likely that there will be a need for more inclusive economic growth strategies to distribute wealth more equitably.

Accommodation for industrialization (IND) with income inequality is positively associated because when industrialization occurs, income inequality increases. This could arise because wealth becomes concentrated in specific industrial sectors or areas, resulting in skewed development. The shift may also represent a movement toward capital-intensive industries that favor only a small portion of the population while widening the wealth gap (Chancel, 2022). This establishes the need for policies to ensure that industry growth is matched by equity in the distribution of benefits. Additionally, population growth (POP) is positively significant. It increases income inequality, which means that population growth could worsen inequality through increased competition for scarce resources and opportunities, particularly in developing areas. Increased population growth strains social services, education, and health systems, affecting disadvantaged groups and widening the income gap, especially in less-endowed economies (Dorn et al., 2024). This finding would indicate the need for population control measures and policies to address challenges caused by rapid demographic transitions.

Table 7. Result for income inequality model.

Variable	Coefficient	Standard error	t- statistics	p –value
T	1.435	0.099	14.444	0.000
GDP	-0.309	1.548	-0.200	0.842
IND	0.345	0.150	2.301	0.026
POP	0.987	0.324	3.041	0.004
CONS	0.015	0.430	0.034	0.972
Goodness of fit test	Adjusted R-squared		0.762	
F-statistic	3.694		Prob > F =0.005	
Durbin-Watson statistics	1.928			
Pesaran CD test	χ^2 (3) = 0.082		Prob> $\chi2$ = 0.934	
Breusch-Pagan LM test	χ^2 (3) = 6.049		Prob> $\chi2$ = 0.109	
Jarque-Bera test	0.072		Prob=0.964	

4.2.3.2. Impact of Income Inequality on Climate Change in SSA

Table 8 emphasizes the basic estimation results of Equation 4 under which the dependent variable is temperature, acting as a climate change proxy, and a final panel least squares regression estimated from the entire sample of three countries spanning 2009-2023. Thus, increased income inequality, as measured by the Gini index, has dramatically increased climate change, as evaluated by rising temperatures. The concepts provide evidence to existing studies that indicate multifaceted relationships between social inequality and climate change (Dias, 2024), especially in developing economies where social and environmental issues tend to be related. This indicates that increased income inequality can aggravate ecological degradation because of unequal access to available resources and under-investment in sustainable development or because it reflects the more significant carbon footprints of more affluent populations, causing the overall increase in climate change (Ige-Gbadeyan, Tanchev, & Mose, 2024). A positive and statistically significant relationship exists between GDP and climate change, implying that economic growth, as measured by per capita GDP, tends to be associated with higher levels of climate change. This could be attributed to economic growth, increased industrial activities and energy consumption, increased greenhouse gas emissions, and global warming, as evidenced in prior works (Grossman & Krueger, 1991; Hasan et al., 2023). Despite economic growth prospects, this calls for a sustainable development policy that balances growth with environmental protection.

The research has found a strong direct relationship between industrialization and climate change, which means that industrial activities that generate heat pose a climate-threatening increase to industrialization. Somewhat, industrialization contributes to emissions from manufacturing processes and energy demand, usually from fossil fuels. This calls for institutional strengthening, as institutional quality is a key intermediary between inequality and climate change. Analysis in Asia indicates that although climate variables, i.e., precipitation and temperature, widen income gaps, better institutional quality is set to close these gaps and mitigate the effects of climate change (Huynh & Hoang, 2024). This finding indicates that environmental degradation is a consequence of industrialization. This highlights the need to adopt green technology and cleaner industrial practices to combat climate change (Bekun, Yadav, Onwe, Fumey, & Ökmen, 2024; Fumey et al., 2024).

Population growth (POP) has had a significant positive effect on climate change, implying that as the population increases, there is increased pressure on environmental resources, and thus emissions and climate change. Population growth accelerates human demand for energy, food, water, and land, translating into ecological degradation. This aligns with a comprehensive review from 1990 to 2019, which shows that the bottom 50% of the global population emitted just 12% of total emissions, while the richest 10% emitted 48%. Significantly, 63% of the worldwide inequality of per-capita emissions is now accounted for by high-to-low-emitting individuals in particular countries, rather than between countries (Chancel, 2022). This result indicates the urgency of sustaining population growth and environmental sustainability policies to minimize the impacts of climate change.

Table 8. Result for climate change model.

Variable	Coefficient	Standard error	t- statistics	p –value
GINI	0.177	0.041	4.319	0.000
GDP	0.007	0.000	10.670	0.000
IND	0.191	0.055	3.421	0.004
POP	1.451	0.660	2.196	0.045
CONS	0.759	1.760	0.431	0.669
Goodness of fit test		Adjusted R-squared	0.550	
F-statistic		1.768	Prob > F =0.090	
Durbin-Watson statistics		2.059		
Pesaran CD test		χ^2 (3)= 0.411	Prob> $\chi2$ = 0.680	
Breusch-Pagan LM test		χ^2 (3) = 6.744	Prob> $\chi2$ = 0.080	
Jarque-Bera test		2.492	Prob=0.287	

Conducting various diagnostic tests was an important step in panel data series modeling. Based on the econometric results, the model passes all diagnostic tests and thus validates the model. The high value of R-squared indicates that the data fit the regression model well.

4.2.3.3. Nexus between Climate Change and Income Inequality in SSA

The Dumitrescu-Hurlin test of panel data on causality indicates a strong, bidirectional relationship between the number of climate change incidents and income inequality in Table 9. A two-way causal nexus exists between climate change (T) and income inequality (GINI), which influence each other. This suggests that both factors affect one another as environmental changes and demographic shifts progress. Consequently, this highlights the complex interrelationship of these variables, as evidenced by the strong reciprocal relationships between climate change and income inequality. The results confirm that climate change and income inequality are linked in SSA. The impact of rising temperatures and droughts disproportionately affects marginalized communities with limited resources, leading to unpredictable growing seasons, crop failures, and sharp increases in food prices. Additionally, an increase in income inequality is associated with escalating climate change. Income disparities mean that marginalized communities are the most affected by the climate crisis. Industrial development (IND) also exhibits bidirectional causality with income inequality, indicating that industrial activities and inequality reinforce each other. Economic growth (POP) does not cause income inequality, indicating no causal link between the two. Similarly, GDP does not cause income inequality or climate change, and climate change does not cause GDP. However, there is bidirectional causality between climate change and industrialization, as well as between climate change and population growth.

Table 9. Results of Dumitrescu Hurlin panel causality tests.

Null hypothesis	W-Stat.	Zbra-Stat.	Prob.	Decision
T → *GINI*	6.789	4.667	0.000	Bi-directional (Reject null)
GINI → *T*	5.544	3.623	0.000	
GDP → *GINI*	1.115	-0.089	0.928	Noncausality (Accept null)
GINI → *GDP*	0.336	-0.742	0.457	
IND → *GINI*	9.106	6.609	0.000	Bi-directional (Reject null)
GINI → *IND*	7.521	5.281	0.000	
POP → *GINI*	2.068	0.709	0.477	Noncausality (Accept null)
GINI → *POP*	2.390	0.979	0.327	
GDP → *T*	0.193	-0.862	0.388	Noncausality (Accept null)
T → *GDP*	0.227	-0.833	0.404	
IND → *T*	6.691	4.585	0.000	Bi-directional (Reject null)
T → *IND*	8.348	5.974	0.000	
POP → *T*	6.519	4.441	0.000	Bi-directional (Reject null)
T → *POP*	4.580	2.815	0.004	

Note: lags 1; Null hypothesis: Does not granger cause.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study investigates the multifaceted linkages between income inequality and climate change in selected SSA countries using the Environmental Kuznets Curve (EKC) and Environmental Justice theories. The causal analysis results confirm that a two-way causal relationship exists from climate change to income inequality in the three countries, suggesting that both variables exert influence over each other. Moreover, industrial growth and population growth worsen income inequality while reducing GDP. The panel regression results support this view, highlighting the complex interplay between economic development, social inequality, and environmental deterioration, with industrial growth and population growth aggravating the negative impacts on the environment and income distribution. The institutional framework of these countries must encompass policies linking environmental conservation and growing inequities. Policies must promote sustainable development while reducing inequalities in light of the interrelationship between economic growth, industrialization, and climate change. Since climate change impacts social groups, it thus becomes necessary to ensure the equitable distribution of environmental resources and mitigate climate change impacts. If SSA economies grow in consonance with environmental protection and social equity, they could break the cycle of ecological degradation and inequality, creating an avenue for sustainability and social justice.

5.2. Recommendations

A key requirement is formulating policies to mitigate climate change and income inequality. To this end, preventing environmental degradation linked to industrialization should be a priority. The study indicates that industrial expansion amplifies climate change and income inequality. Therefore, stringent environmental regulations concerning industries should accompany the prioritization of green technologies to reduce environmental degradation and ensure that economic growth is not disproportionately skewed toward already disadvantaged communities. Such measures will only be feasible through incentives for industries to shift towards less-polluting production methods, sustainable practices that limit carbon emissions, and resource consumption.

At the same time, because the increasing population adversely affects income distribution worldwide, measures to control population growth and improve access to family planning services are equally pertinent. Information and education programs on the advantages of family planning can empower communities, especially in rural areas, to make independent choices regarding family size. Investment should also be made in healthcare, specifically maternal and child health services, to alleviate suffering, reduce poverty, and decrease income inequalities caused by rapid population growth. These actions must be embedded within broader development strategy frameworks, complementing economic growth with social well-being.

Another critical recommendation is improving economic opportunities in underprivileged sectors to combat income inequality. Since economic growth correlates with reduced inequality, equitable access to resources and opportunities becomes imperative. Such policies would include investing in education, vocational training, and skills development for marginalized communities, where participation can benefit all. Moreover, productivity and income would improve by promoting entrepreneurship and providing modern technologies to small-scale farmers, reducing the wealth gap. All these measures will also go a long way towards lowering social disparities while being environmentally sustainable.

Last, environmental justice principles should be incorporated into climate change policies. The study shows that climate change exacerbates inequality by increasing disparities among vulnerable populations. To address this, policy design should prioritize marginalized communities in climate adaptation and mitigation plans. Such vulnerable groups will be involved in measures to ensure access to climate-resilient infrastructure, flood defenses, drought-resistant crops, and improved water management systems. Public participation in climate decision-making processes will ensure that the voices of those most affected by climate change are heard, fostering equitable and practical solutions. By integrating environmental justice into specific climate policies, countries in East Africa can address ecological degradation and social inequality in a holistic and sustainable manner.

5.3. Suggestions for Future Studies

Future research will likely include various countries across SSA and elsewhere, allowing for an even more extensive view of the income inequality-climate nexus. Additional findings of country-specific patterns and perspectives would be uncovered through new-member countries with different levels of industrialization, economic development, and climate vulnerability. Longitudinal studies on these dimensions would provide an in-depth understanding of the long-term impacts of climate change and economic growth on social inequality. Such an expanding focus might sharpen policy recommendations and improve the design of environmental sustainability and social equity interventions.

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