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Climate Action, Security Dynamics, and Economic Stability in Sub-Saharan Africa

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ABSTRACT
In Sub-Saharan Africa (SSA), climate change and insecurity pose increasing threats to economic viability, but little is known about how they interact. To close this gap, this study looked at how security dynamics and climate variability combine to affect long-term economic paths, especially in fragile developing economies. The justification is the pressing need to comprehend how stressors associated with the environment and conflicts erode institutional resilience and capital investment. Using panel data on 32 of 46 African countries ranging between 2000 and 2023, divided into low- and middle-income economies, the study employed the Common Correlated Effects Mean Group (CCEMG) technique. The findings in Model A showed that the level of insecurity (INS) has a significant negative impact on economic growth (ES) across the full sample, LICs, and MICs, in both the short-run and long-run. In Model B, climate action was integrated into national security to examine its moderating effect on the nexus between economic sustainability and insecurity in SSA. The interactive variable (LNS_CC) exhibits a negative and significant relationship with economic sustainability (ES) in the full sample and LICs in both the short-run and long-run. However, in MICs, LNS_CC shows a positive relationship with economic growth in both the short-run and long-run. Thus, the study recommended that SSA countries, through the relevant security departments, should promote the Committee on Climate Action and Green Economic Development to successfully tackle the interplay of security and climate change.

Keywords: Sub-Sahara African (SSA), CCEMG, Climate Action, Security framework, and Insecurity
JET Code: Q54, O55, E02, H56, C33.

1 INTRODUCTION

In Sub-Saharan Africa, "security vulnerabilities" refers to structural flaws that put nations, societies, and economies at risk of instability, violence, and a collapse in governance. These weaknesses frequently show up as resource competition, permeable borders, weak conflict resolution processes, and brittle institutions, all of which reduce a state's ability to successfully avoid or address security threats (Krampe et al., 2021). By increasing resource scarcity, population displacement, and competition for land, water, and livelihoods, climate change makes these vulnerabilities worse (Ide et al., 2021). For instance, annual flooding in East Africa has forced populations to relocate, making it easier for armed groups to recruit and operate, while frequent droughts in the Sahel have escalated conflicts between pastoralists and farmers (Nyadera & Onditi, 2022).

The threat posed by climate change to international security is becoming more widely acknowledged. Although there is ongoing discussion on the precise role of climate change in conflicts, there is increasing agreement that it serves as a "threat multiplier," intensifying pre-existing vulnerabilities and conflict drivers (Obaze et al., 2022). For instance, severe weather, sea level rise, and ongoing droughts have exacerbated socioeconomic disparities, increased food and water insecurity, and heightened competition for limited resources, thereby influencing economic growth (Busby et al., 2018). According to research, there is a 10–20% increase in the chance of violent conflict for every 0.5°C increase in temperature (Hsiang et al., 2013). Additionally, Craig et al. (2021) discovered that a higher frequency of terrorist incidents was linked to temperature rises, which results in scarcity of economic resources in 159 countries between 1970 and 2015.

Researchers also point out that security risks are multifaceted, encompassing economic insecurity (poverty, joblessness), human insecurity (disturbances, health crises), and physical insecurity (terrorism, armed violence). Sub-Saharan economies are especially vulnerable to climate-related shocks as a result of their persistence, which erodes resilience (Adams et al., 2023; von Uexkull & Buhaug, 2021). Therefore, the phrase "security vulnerabilities" is used in this study to refer to the combined institutional, social, and environmental flaws that make Sub-Saharan Africa a breeding ground for conflict, instability, and diminished economic viability.

Despite having some of the greatest security vulnerabilities associated with climate change, Sub-Saharan Africa makes up the smallest portion of the world's greenhouse gas emissions. This contradiction results from the region's long history of resource-driven conflicts, ethnic tensions, and political turmoil, as well as its significant reliance on climate-

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sensitive industries like pastoralism and rain-fed agriculture (Brown and Crawford, 2008). When former UN Secretary-General Ban Ki-Moon stated in 2007 that the Darfur crisis, which is frequently presented as an ethnic war, has its origins in ecological degradation brought on by climate change, he highlighted this complexity (Brown and Crawford, 2009).

Climate change has been specifically acknowledged as a national security threat in many African countries. According to the National Climate Change Policy (2021–2030), war, displacement, and economic instability are all exacerbated by damage to the environment, increasing temperatures, and changes in the pattern of rainfall. According to Okpara et al. (2016), this is especially noticeable in the Lake Chad Basin, where water levels have decreased by 90% since 1960, impacting over 30 million people in Nigeria, Chad, Niger, and Cameroon. The ensuing displacement and food insecurity have contributed to the rise of militant organizations like Boko Haram. The UN Security Council recognized this fact in 2017 when it issued Resolution 2349, which recognized how environmental concerns, such as drought and desertification, threaten peace and security in Africa (UN Security Council, 2017). Cross-border migration and competition for limited resources have increased in the Sahel due to extended drought and desert encroachment. Nigeria, a country with a large population and a central Sahelian location, confronts additional difficulties due to security concerns, poor governance, and climate sensitivity.

The Lake Chad Basin provides a striking example of this intersection. More than half of the population depends on cattle, fishing, and agriculture—all of which are becoming more and more endangered due to desertification. Since 2018, the conflict between farmers and pastoralists in Nigeria's Middle Belt, which includes Adamawa, Benue, Nasarawa, Plateau, and Taraba, has gotten worse. Over 300,000 people have been displaced by these conflicts, which are sparked by population movement, resource competition, and land degradation (IDMC, 2019).

It is imperative that national and regional security frameworks incorporate resilience and climate adaptation strategies in order to lessen these threats. According to the CNA Military Advisory Board (2014), climate change is a "catalyst for conflict" and should be considered a key component of security strategy. This entails tying environmental sustainability to disaster preparedness, peacebuilding, and socioeconomic growth in Sub-Saharan Africa. Regretfully, the majority of regional national security plans continue to be reactive and inadequately aligned with climate policy. The ability of Sub-Saharan Africa to adapt to exacerbated dangers is hampered by the absence of coherence between security strategy and climate policy. By investigating the ways in which security dynamics and climate change interact to influence economic outcomes, this study aims to close the gap. It specifically investigates the degree to which security can be strengthened or weakened by climate action, the impact of insecurity on investment and economic growth, and the best policy frameworks for promoting resilience.

2 LITERATURE REVIEW/RELATED WORK

2.1 EMPIRICAL REVIEW

Examining how climate change affects economic growth in 43 Sub-Saharan African economies, Chamma (2024) looked at how sectoral disparities are obscured by aggregate climate shocks. Employing a production-function framework and utilizing a fixed-effects model and regressions that appeared to be unrelated, the study discovered that unpredictable rainfall and rising temperatures lower GDP per capita, with agriculture bearing the brunt of this decline. The lack of post-2020 security variables was the drawback. It was suggested that governance and conflict exposure be combined in future studies. This disparity is closely related to our research, which integrates security flaws into the relationship between the economy and climate.

Blimpo (2024) examined the process by which African economies are impacted by climate change. The study compiled factual data for decision-makers, with an emphasis on high exposure and limited fiscal space. Although not using panel econometrics, the study emphasized the dangers of postponing adaptation for structural change. One drawback was the lack of quantifiable causality, but it was concluded that macro stability and adaptation investments should be linked in future studies. By examining the causal relationships between climate, security, and stability, our work advances this gap. The effect of climate on African growth by climatic zones was examined by Zhao et al. (2023). Using panel vector autoregressions and panel fixed effects, framed by the Environmental Kuznets Curve, they discovered that agriculture is more vulnerable to growth losses in equatorial zones. The exclusion of insecurity variables was the limitation of this study. Our research uses security as a mediating variable to close the gap left by the study's recommendation to integrate socio-political shocks with climate dynamics.

The impact of armed conflict on growth with spatial spillovers in SSA was examined by Ogbe et al. (2024). They showed, particularly in Central Africa, that war inhibits growth and spreads across borders using spatial econometric models (SDM, SAR, and SEM). The drawback was the lack of climatic factors. They proposed incorporating environmental stressors into the link between growth and security. By explicitly modeling the links between climate change and security, our study makes a great contribution. Efayena et al. (2024) investigated macro-outcomes, military spending, and terrorism. The study used quantile ARDL and causality techniques and found that, although the effects vary by income level, terrorism impedes growth. The exclusion of climate change was a major limitation. They suggested looking into how environmental deterioration could increase the financial cost of terrorism, and this is advanced in our

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work by incorporating climate action indicators with insecurity.

Özkaya (2022) examined the relationship between growth and terrorism in 18 SSA nations. The study discovered a reciprocal relationship using panel causality methodologies, with insecurity being both depressing and driven by subpar economic performance. There were no climate-related shocks. The suggestion that future studies should examine the relationship between security dynamics and environmental stressors is clearly accomplished by our study's explicit testing of climate-security routes. Adegboyo et al. (2025) investigated whether financial development lessens the relationship between conflict and climate change. They discovered that deeper financing reduces the impact of climate shocks on conflict by using econometric models with interaction terms. One drawback was that the outcome of macroeconomic stability was not investigated. Their recommendation that future research link stability in general to financial resilience is addressed by this study, testing how both climate action and security shape overall economic stability.

The relationship between trade and climate vulnerability in SSA was examined by Aurélien et al. (2025). They demonstrated how trade openness changes vulnerability and adaptive potential using country-time fixed effects. The exclusion of insecurity interruptions in commerce networks was the constraint. They suggested that conflict dynamics be included by integrating security vulnerabilities into the relationship between climate, trade, and stability, which is bridged by our study. Mamman et al. (2023) investigated inclusive growth and climate change in Africa. They discovered, using panel econometrics, that climate shocks exacerbate inequality and impede inclusive growth. The primary constraint was the lack of security variables. They suggested including conflict and governance indices. This is furthered by your study, which combines security, climate action, and inclusivity to explain economic stability.

As evident from the above reviews, the majority of research conducted in Sub-Saharan Africa looks at insecurity and climate change independently, paying little attention to how they interact to impact economic sustainability. The relationship between the economy, security, and climate is not well conceptualized because, even when connections are recognized, insecurity is frequently viewed as a result rather than a mediating factor. To bridge that gap, this study models security as a mediating variable in the relationship between economic stability and climate action. It offers fresh evidence on how security and climate combine to influence economic results using contemporary panel data and sound econometric techniques, providing both theoretical support and practical policy insights.

2.2 THEORETICAL FRAMEWORK

Threat multiplier theory, the human security framework theory, the ecological marginalization theory, and institutional capacity theory are some of the theories that make up the study's theoretical framework. This theoretical structure shows how security and climate action interact and affect economic sustainability. It draws from these various theories in environmental economics, security studies, and sustainable development to explain the complex relationships and interactions among these factors. The sustainable development theory posits that economic growth, environmental protection, and social equity are interconnected and essential for long-term prosperity.

A mathematical model is constructed to capture the dynamic relationships between economic sustainability, climate change, and security as follows;

Economic Sustainability Function: Economic sustainability is built as a function of climate action, security, and control variables.

$$ES_t = f(C_t, S_t, Z_t) \quad (1)$$

Climate Change Function: Climate action is influenced by security and control variables.

$$C_t = g(S_t, Z_t) \quad (2)$$

Security Function: Security is influenced by climate action and control variables

$$S_t = h(C_t, Z_t) \quad (3)$$

Where; ES denotes economic sustainability, C denotes climate change, S denotes security, and Z denotes control variables.

To capture the dynamic interactions over time, we use a system of differential equations

$$\frac{\partial ES_t}{dt} = \alpha_1 C_t + \alpha_2 S_t + \alpha_3 Z_t + \varepsilon_{ES} \quad (4)$$

$$\frac{\partial C_t}{dt} = \beta_1 S_t + \beta_2 Z_t + \varepsilon_C \quad (5)$$

$$\frac{\partial S_t}{dt} = \gamma_1 C_t + \gamma_3 Z_t + \varepsilon_S \quad (6)$$

Where: αi, βi, γi are coefficients indicating the strength and direction of influence and ε_i are the error terms capturing unobserved factors respectively.

Equilibrium Analysis: The equilibrium points can be found by setting the derivatives to zero:

$$\frac{\partial ES_t}{dt} = \frac{\partial C_t}{dt} = \frac{\partial S_t}{dt} = 0 \quad (7)$$

Solving these equations simultaneously provides the equilibrium values for E, C, and S:

E*, C*, S*

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Using Jacobian matrices, the consistency of the points of equilibrium can be examined. For the system, the Jacobian matrix J is provided by:

$$J = \begin{vmatrix} \frac{\partial ES}{\partial C} & \frac{\partial ES}{\partial S} & \frac{\partial ES}{\partial Z} \\ \frac{\partial C}{\partial C} & \frac{\partial C}{\partial S} & \frac{\partial C}{\partial Z} \\ \frac{\partial S}{\partial C} & \frac{\partial S}{\partial S} & \frac{\partial S}{\partial Z} \end{vmatrix} = \begin{vmatrix} \alpha_1 & \alpha_2 & \alpha_3 \\ 0 & \beta_1 & \beta_2 \\ \gamma_1 & 0 & \gamma_2 \end{vmatrix} = 0 \quad (8)$$

3 METHODOLOGY

3.1 EMPIRICAL MODEL SPECIFICATION

Elasticity is used to express how the independent variables affect the economic stability (Y).

$$Y = f(CC, NS, GOQ, GCI) \quad (9)$$

where $CC, NS, GOQ, and\ GCI$ denote total climate change (action) (proxied by CO_2), national security (a proxy by military/defense annual budget), governance quality and gross capital investment, in that order. The determinants are all expressed in logarithms (rep by the prefix "ln") except the GOQ which is in percentile.

Equation (9) is represented explicitly as;

$$ln\,Y = \beta_0 + \beta_1 CC_{i,t} + \beta_2\, ln\, N\, S_{i,t} + \beta_3 GOQ_{i,t} + \beta_4\, ln\, G\, CI_{i,t} + \varepsilon_{i,t} \quad (10)$$

where i represents a cross-section of countries; t stands for the years 1996 to 2020; β_0 is the intercept; β_1- β_4 are each variable's elasticities; and ε is the noise (error).

In this paper, we investigated how the incorporation of climate action into the security framework among sub-Saharan African economies will impact economic stability. Equation (11), which provides a rich method of modeling the moderating impact of climate action on the link between economic stability and level of security in SSA, thereby captures the conditional impacts. The conditional effect is represented by including the product of the national security and climate action as one of the explanatory factors in the equation.

$$ln\,Y = \beta_0 + \beta_1 CC_{i,t} + \beta_2\, ln\, N\, S_{i,t} + \beta_3\, ln\, N\, S_{i,t} * CC_{i,t} + \beta_4 GOQ_{i,t} + \beta_5\, ln\, G\, CI_{i,t} + \varepsilon_{i,t} \quad (11)$$

where NS*CC is the interactive term of national security and climate action; and all other factors stay the same as they were before. The total impact of national security which includes the marginal influence of climate on the economic stability is arrived at by taking partial derivatives of equation (11):

$$\frac{\partial Y_{i,t}}{\partial NS_{i,t}} = \beta_2 + \beta_3 CC_{i,t} \quad (12)$$

The sign and magnitude of this equation should be considered while interpreting it. Considering the sign, if $\beta_2 > 0$ and $\beta_3 < 0$, national security deteriorates economic stability (Y) only when climate action promotes resources scarcity. However, if $\beta_2 < 0$ and $\beta_3 > 0$, it implies that using improved level of resources via climate would make national security enhance economic stability (Y). Meanwhile, if $\beta_2 > 0$ and $\beta_3 > 0$, then national security and climate action complementarily promote economic stability (Y). Lastly, if $\beta_2 < 0$ and $\beta_3 < 0$, the nexus of interplay of national security and climate action has amplifying diminishing influence on economic stability. Considering the magnitude, if $\frac{\partial EY_{i,t}}{\partial ENS_{i,t}} > 0$, the interplay of national security with climate action enhances economic stability (Y) but if $\frac{\partial Y_{i,t}}{\partial NS_{i,t}} < 0$, the interplay of national security with climate action dampens economic stability (Y) in the sampled SSA countries.

3.2 ESTIMATION TECHNIQUE

individual dimension, which is consistent with the structure of our dataset. The CCEMG estimator applies supplementary regressors, the individual means of the independent X and dependent V variables, to reduce inter-individual dependence. Pesaran (2006) showed that these averages take into consideration common factors that are not observed. To address the various effects of these common factors, the equation is estimated for each individual, and then the coefficients are averaged over the entire panel using a mean group (MG) approach. Chudik and Pesaran (2015) state that the CCEMG estimator is still resistant to externalities and worldwide shocks. The CCEMG method's calculated coefficient can be represented as follows:

$$\tilde{\alpha}_{CCEMG} = N^{-1} \sum_{i=1}^{N} \tilde{\alpha} \quad (13)$$

Eberhardt (2012) points out that the CCEMG estimator treats common components as nuisance parameters, which might pose issues in some empirical investigations due to the difficult-to-interpret means. Eberhardt, on the other hand, suggests the AMG estimator, which takes the stance that common components constitute an estimable common dynamic process (CDP) rather than treating them as nuisance parameters. Three steps are taken by the AMG estimator to solve the identification problem:

First action: Equation 14 estimates a pooled differenced Ordinary Least Squares (OLS) model using T-1 dummy time variables. The common dynamic process (CDP) is then designated after the coefficients of these time dummies that are gathered.

$$\Delta V_{it} = \grave{b}\, \Delta X_{it} + \sum_{i=1}^{N} c_t DUMMY_t + v_{it} \quad (14)$$

Step two: The CDP is included to the group-specific model by either being included explicitly in the model or by deducting it from the dependent variable in each group.

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$$\tilde{V}_{it} = V_{it} - CDP \quad (15)$$

Third step: Using the Mean Group (MG) model proposed by Pesaran and Smith (1995), the model is computed for each panel member individually, and the mean of the calculated coefficients is subsequently determined using equation (13).

This estimator (CCEMG) examines the link among independent variables at various points in the dependent variable's conditional distribution while taking into consideration simultaneously the existence of CD and the heterogeneity of the coefficient slope. This approach offers a comprehensive understanding of the interactions between the drivers and natural resource dependence. Before conducting the aforementioned estimates, we performed various tests to assess slope homogeneity, inter-individual dependence, stationarity, and cointegration.

We first carried out some basic testing before applying the CCEMG estimator. These include the panel unit root test, slope homogeneity test, cross-sectional dependence (CD) test, and panel cointegration test. In an attempt to avoid unclear and biased estimates in panel data analysis due to differences in spatio-temporal features and spatial effects, a CD test must be performed (Afolabi, 2023; Majeed et al., 2022).

It is imperative to conduct the test for slope homogeneity across the cross-sectional units following the CD test in order to account for the differences in the demographics and socioeconomic profiles of these SSA countries. If slope heterogeneity fails to be taken into consideration, the estimated values may be illogical (Afolabi, 2023; Zuo et al., 2022).

We performed the panel unit root test subsequent to the slope homogeneity and CD testing. We employed Pesaran (2007) second-generation cross-sectional augmented CADF and IPS (CIPS) with Hadri to determine the sequence in which each variable is integrated and to explain the cross-sectional dependence among the countries in our sample.

To evaluate the state of the long-term relationships between the variables, the panel cointegration test is conducted. The Westerlund test was created by Westerlund in 2007 and, unlike more popular cointegration techniques like Kao and Pedroni, it provides objective results while accounting for CD and heterogeneity.

3.3 Data Descriptions and Sources

The study involved 32 out of 46 SSA nations because of data accessibility issues. The 32 countries that were chosen (refer to the appendix) are split into two economic categories: low-income and middle-income. According to the World Economic Outlook (2019), middle-income economies have per capita gross national incomes exceeding $995, whereas low-income economies had per capita gross national incomes of $995 or less in the years 2015–17. We used secondary data that was released annually between 2000 and 2023. Table I displays the variables' descriptions and sources.

TABLE I: DATA DESCRIPTIONS AND SOURCES

Variables	Definition	Description	Data Source
CC	Climate Change	Captured with carbon emissions (CO_2) measured in kilo tonnes	WDI, 2024
ES	Economic Stability	RGDP	WDI, 2024
NS	National Security	Military expenditure by country, in constant (2022) US$m	SIPRI 2023
IN	Insecurity	Political Stability and Absence of Violence/Terrorism: Percentile Rank	World Governance Indicator (2023)
GCI	Gross Capital Formation	Gross capital formation (US$)	WDI, 2024
GEQ	Governance Quality	Captured with quality of regulations (in Percentile Rank)	World Governance Indicator (2023)
NS*CC	Interplay of Climate Action with Security	Captured with multiplication climate Action and National Security	Derived

Source: Author's Compilation

4 RESULTS AND DISCUSSION

The preliminary analysis is discussed in this section, with formal pre-estimation analysis involving generating statistical summaries, conducting descriptive analyses, and creating graphical representations of the data. Also, the preliminary analysis is concluded by examining whether the series under investigation contains any unit roots.

4.1.1 Descriptive Statistics

Descriptive statistics summarising the entire sample, comprising both low-income (LICs) and middle-income (MICs) nations, are shown in Table II. The table shows important metrics for each variable, including the mean, maximum, minimum, and standard deviation. The Jarque-Bera test statistic is utilized to investigate distribution normality in greater detail.

Regarding average values, the economic sustainability (ES) for all sampled countries averages at US$4.03 trillion in constant US dollars. Climate Change (CC) averages 20,483 kt for the full sample, 4,314 kt for LICs, and 45,359 kt for MICs. Gross Capital Investment (GCI) averages US$22.9 billion for the full sample, US$22 billion for LICs, and US$23 billion for MICs. National Security (NS) averages US$658 billion for the full sample, US$459 billion for LICs, and US$963 billion for MICs. Gross Capital Investment averages US$22.42 billion for the full sample, US$20.91 billion for LICs, and US$24.10 billion for MICs. Governance

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quality rank percentiles are 30.9% for the full sample, 23.8% for LICs, and 41.9% for MICs, while insecurity (INS) percentiles are 32.1% for the full sample, 26.8% for LICs, and 40.9% for MICs.

The significant disparity between the maximum and minimum statistics is highlighted by the high standard deviation values. However, direct comparison of standard deviation across variables is not valid due to differences in units of measurement. To enable comparison, standard deviation statistics were normalized. Notably, ES, CC, and NS exhibit the highest volatility for the full sample, LICs, and MICs, as indicated by their relatively higher standard deviation values compared to other variables.

Regarding the statistical distribution, the Jarque-Bera test produces probability values below 0.05 for the full sample, LICs, and MICs, signifying the rejection of the normal distribution hypothesis at the 5% significance level.

4.1.2 GRAPHICAL ANALYSIS

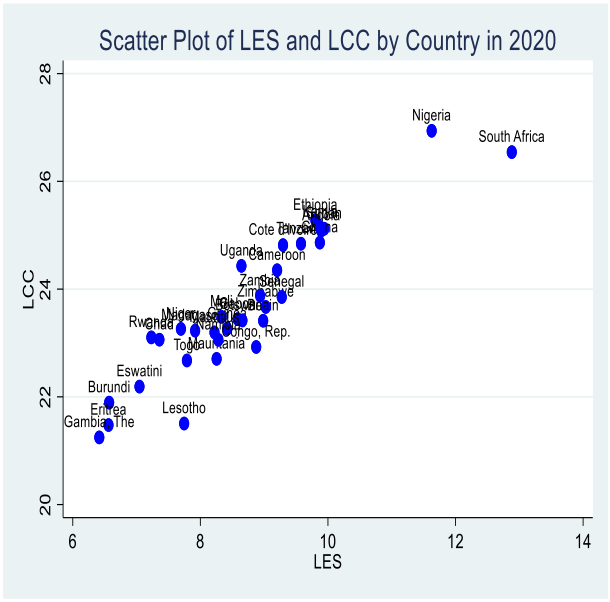
As depicted in Figure 1a, the relationship between Climate Change (CC) and Economic Sustainability (ES) across the 32 selected sub-Saharan African (SSA) countries illustrates a distinct pattern. For example, in 2020, both Nigeria and South Africa displayed high levels of ES coupled with high levels of CC. Conversely, nations such as Burundi, Lesotho, the Gambia, and Eritrea exhibit a low correlation between ES and CC. Overall, there is a consistent positive correlation between ES and CC. The analysis demonstrates a positive correlation between Economic Sustainability and Climate Change across the selected SSA countries, with notable variations among different nations. Countries with higher economic sustainability tend to experience higher levels of climate change, highlighting the intertwined nature of economic and environmental factors.

As depicted in Figure 1b, the relationship between National Security (NS) and Economic Sustainability (ES) across the 32 selected sub-Saharan African (SSA) countries reveals a distinct pattern. For instance, in 2020, both Nigeria and South Africa demonstrated high levels of ES alongside high levels of NS. In contrast, countries such as Lesotho, the Gambia, and Eritrea show a low correlation between ES and NS. Overall, there is a consistent positive correlation between ES and NS. The analysis highlights a positive correlation between National Security and Economic Sustainability among the selected SSA countries, with significant variations across different nations. Countries with higher economic sustainability tend to experience higher levels of national security, underscoring the interconnectedness of economic and security factors.

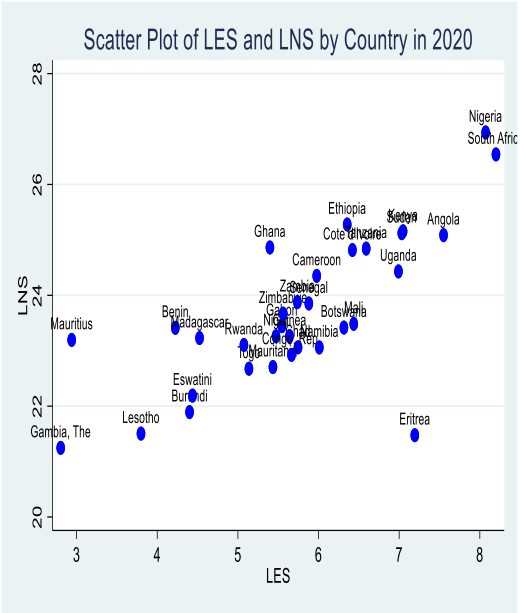
TABLE II: DESCRIPTIVE STATISTICS

Full Sample Countries					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
CC	792	20483.92	70067.99	159.6	448298
ES	792	4.03E+10	8.48E+10	9.60E+08	5.19E+11
NS	792	658.029	1136.949	0	7085
INS	768	32.203	21.892	0.529	93.75
GCI	792	22.875	9.095	1.525	79.401
GOQ	792	30.987	18.974	0.472	86.058
NS CC	792	55192890	2.42E+08	0	1.71E+09
Low Income Countries					
CC	480	4314.842	4592.831	159.6	22131.5
ES	480	1.72E+10	2.16E+10	9.60E+08	1.00E+11
NS	480	459.514	956.654	0	6719.2
INS	456	26.31	17.395	0.529	74.603
GCI	480	22.205	9.172	1.525	60.156
GOQ	480	23.89	13.756	0.472	73.932
NS CC	480	4140322	14655365	0	1.03E+08
Middle Income Countries					
CC	312	45359.42	106911.9	806.3	448298
ES	312	7.59E+10	1.24E+11	2.49E+09	5.19E+11
NS	312	963.438	1312.93	14.645	7085
INS	312	40.815	24.778	0.971	93.75
GCI	312	23.907	8.892	11.825	79.401
GOQ	312	41.905	20.662	6.667	86.058
NS CC	312	1.34E+08	3.72E+08	36467.2	1.71E+09

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(a)



(b)

Figure 1: Graphical Analysis

4.1.3 CORRELATION ANALYSIS

We evaluated both the strength and direction of correlations between the relevant predictors using a correlation test. This analysis aimed to investigate potential multicollinearity. Table III displays the correlation test findings, which indicate moderate relationships between all the variables under consideration. Economic sustainability (ES) displays the strongest association with carbon emissions across Low-Income Countries (LICs), Middle-Income Countries (MICs), and the overall dataset. These findings indicate that multicollinearity is not a concern within the model, as no notably strong correlations exist among the variables. Therefore, incorporating all independent variables into the empirical model does not raise issues related to multicollinearity.

4.1.4 CROSS-SECTIONAL DEPENDENCE

Panel analyses need the assessment of cross-sectional dependence (CD) because the countries in the sample differ in many ways. Table IV displays the findings of the Pesaran CD test, which show that at the 1% significance level, the null hypothesis that there is no CD is rejected. This result implies that additional countries in the sample may be impacted by the dynamics of variables like LCC_NS, Insecurity, National Security, Gross Capital Investment, and Climate Change. It suggests that middle-income and low-income nations in Sub-Saharan Africa (SSA) depend on one another. This result essentially emphasizes how interrelated the countries of Sub-Saharan Africa are.

TABLE III: CORRELATION RESULTS

FULL SAMPLE							
Variables	-1	-2	-3	-4	-5	-6	-7
CC	1						
ES	0.75	1					
NS	0.52	0.63	1				
INS	-0.02	-0.2	-0.26	1			
GCI	-0.11	-0.1	-0.03	0.08	1		
GOQ	0.22	0.04	-0.14	0.69	0.01	1	
NS_CC	0.99	0.72	0.54	-0	-0.11	0.22	1
LOW INCOME COUNTRIES							
CC	1						
ES	0.88	1					
NS	0.48	0.68	1				
INS	-0.27	-0.4	-0.36	1			
GCI	0.04	0.13	-0.03	-0	1		
GOQ	-0.27	-0.2	-0.36	0.56	0.18	1	
NS_CC	0.61	0.72	0.93	-0.3	-0.05	-0.27	1
MIDDLE INCOME COUNTRIES							
CC	1						
ES	0.73	1					
NS	0.64	0.71	1				
INS	-0.15	-0.4	-0.36	1			
GCI	-0.23	-0.2	-0.08	0.14	1		
GOQ	0.15	-0.2	-0.22	0.72	-0.25	1	
NS_CC	0.99	0.7	0.65	-0.1	-0.22	0.15	1

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TABLE IV: CROSS-SECTIONAL DEPENDENCE

FULL SAMPLE COUNTRIES				
Variable	**CD-test**	**p-value**	**corr**	**abs(corr)**
LCC	67.53	0.000	0.622	0.699
LES	91.74	0.000	0.845	0.846
LNS	38.72	0.000	0.357	0.543
INS	-0.85	0.398	-0.008	0.361
LGCI	6.32	0.000	0.058	0.371
GOQ	3.99	0.000	0.037	0.435
LCC_NS	73.62	0.000	0.657	0.680
LOW INCOME COUNTRIES				
LCC	35.29	0.000	0.556	0.69
LES	50.56	0.000	0.795	0.801
LNS	15.22	0.000	0.241	0.482
INS	1.47	0.143	0.024	0.397
LGCI	8.35	0.000	0.132	0.394
GOQ	2.1	0.036	0.034	0.454
LCC_NS	41.23	0.000	0.616	0.648
MIDDLE INCOME COUNTRIES				
LCC	30.96	0.000	0.716	0.72
LES	39.72	0.000	0.918	0.918
LNS	25.64	0.000	0.593	0.633
INS	0.02	0.981	0.001	0.334
LGCI	-0.9	0.366	-0.021	0.361
GOQ	0.34	0.737	0.008	0.399
LCC_NS	32.11	0.000	0.742	0.746

4.1.5 ANALYSIS OF THE UNIT ROOT

In this section, we present the outcomes of unit root tests, pivotal for the standard inference procedure to distinguish between stationary and non-stationary variables. To ensure robustness and consistency, multiple unit root tests are employed, including Pesaran's CADF test, Hadri Unit Root Test, and Breitung unit-root test. Notably, all tests are performed on the natural logarithm of the series, except for Insecurity (INS) and Governance quality (GOQ), which are already expressed as percentages.

Following the CD test, stationarity tests utilizing suitable techniques are imperative. The Pesaran's CADF test, Hadri Unit Root Test, and Breitung unit-root test, adept at handling CD concerns, are introduced by Pesaran (2007). Table 5 delineates the outcomes of these methods, revealing a heterogeneous order of integration across the three models. While only one series achieves stability at (I(0)), others necessitate first-order differencing (I(1)). This condition fulfills a prerequisite for employing the CCEMG framework. The identification of variable stability raises the prospect of cointegration, prompting the need for a cointegration test to explore this potential further.

4.1.6 ANALYSIS OF HOMOGENEITY SLOPE

The homogeneity slope test is vital in panel data analysis as it determines whether the relationships between variables are consistent across different groups or entities within the panel. This test specifically assesses if the slope parameters of the regression model are uniform across all panel units. Conducting this test ensures the robustness and accuracy of panel data analysis results, enhancing the credibility of research findings and conclusions.

Before panel data estimation, it is essential to verify the status of slope parameters to avoid inconsistent estimators. Both Model A, which excludes an interactive term, and Model B, which includes an interactive term of energy consumption and financial inclusion, undergo the slope homogeneity test. The findings, which are based on the slope homogeneity test, are shown in Table VI and disprove the null hypothesis that the slope parameters are constant over the three panels. This outcome highlights the variability in slopes among the sampled nations, indicating that Sub-Saharan African nations exhibit differences in their levels of economic sustainability (ES) and Climate Action (CC), among other factors.

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TABLE V: ANALYSIS OF UNIT ROOT

Test	CADF		HADRI		Breitung		
Variables	**Level**	**First Diff**	**Level**	**First Diff**	**Level**	**First Diff**	**Order of Int**
FULL SAMPLE COUNTRIES							
LCC	-2.28***	-2.52***	74.92***	0.456	6.674	-11.49***	I(1)
LES	-1.98*	-1.86	78.03***	12.79	11.81	-12.18***	I(1)
LNS	1.16	-4.70***	41.15***	-4.162	2.740	-9.189***	I(1)
INS	-2.19***	-2.77***	39.68***	-1.652	-1.738**	-10.65***	I(0)
LGCI	-1.81	-2.65***	35.74***	-1.619	-1.278	-11.85***	I(1)
GOQ	-1.52	-2.75***	54.79***	-2.517	-0.571	-12.06***	I(1)
LCC_NS	-2.47***	-3.72***	35.35***	-4.910	5.728	-9.260***	I(1)
LOW INCOME COUNTRIES							
LCC	-2.245**	-2.235**	58.37***	0.960	5.955	-8.772***	I(0)
LES	-2.245**	-2.104*	1.215***	7.982**	9.474	-8.774***	I(1)
LNS	-1.793	-2.137**	29.17***	-3.378	2.758	-7.216***	I(1)
INS	-2.006	-2.792***	34.49***	-2.014	-0.658	-8.841***	I(1)
LGCI	-1.839	-2.664***	30.77***	-1.523	-0.459	-8.791***	I(1)
GOQ	-1.849	-2.700***	41.65***	-1.533	0.016	-9.344***	I(1)
LCC_NS	-1.719	-2.134**	23.20***	-3.879	4.943	-8.624***	I(1)
MIDDLE INCOME COUNTRIES							
LCC	-2.092	-2.493***	46.92***	-0.647	3.081	-7.439***	I(1)
LES	-2.123**	-1.819	48.31***	10.76***	7.088	-8.795***	I(1)
LNS	-1.500	-2.312**	36.94***	-0.803	1.030	-5.690***	I(1)
INS	-1.470	-2.854***	16.53***	0.167	-2.104	-6.158***	I(1)
LGCI	-1.397	-2.018	14.80***	-0.316	-1.631	-8.028***	I(1)
GOQ	-1.234	-2.920***	35.81***	-2.104	-1.128	-7.631***	I(1)
LCC_NS	-1.970	-2.404***	44.58***	0.009	3.063	-4.636***	I(1)

Source: Author's Computation (2024) Stationary at 1% (*), 5% (**) and 10% (***)

The findings from the homogeneity slope test suggest that the relationship between Economic Sustainability (ES) and Climate Action (CC) is not uniform across Sub-Saharan African nations. This variability underscores the need for tailored policy approaches that consider the unique circumstances of each country within the region. Ensuring the robustness of panel data analysis through the homogeneity slope test enhances the reliability of research conclusions, providing a nuanced understanding of how ES and CC interplay across diverse national contexts.

4.1.7 ANALYSIS OF COINTEGRATION

The Westerlund (2007) second-generation test is widely employed to evaluate cointegration within panel data models, offering valuable insights into long-term relationships among variables. This analysis is presented in Table VII.

The adjusted DF test statistics in Model A, which includes the Full Sample Size, Low-Income Countries (LICs), and Middle-Income Countries (MICs), are statistically significant at the 1% level, providing strong support against the null hypothesis that there is no cointegration. This result is strengthened by the remarkably low p-value of 0.0001, which offers strong confidence in rejecting the null hypothesis. Comparably, although with minimal significance, the Augmented Dickey-Fuller (ADF) test yields statistically significant results at the 1% level. In general, the null hypothesis is substantially rejected by all three of the other statistical tests, indicating the possibility of cointegration among the chosen sampling countries.

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TABLE VI: ANALYSIS OF HOMOGENEITY SLOPE

Full Sample				
	Model A		Model B	
	SH	ASH	SH	ASH
Value	27.421	30.819	20.29	24.12
Prob	0.000	0.000	0.000	0.000
	Low-Income Countries			
Value	21.98	24.701	17.20	20.47
Prob	0.000	0.000	0.000	0.000
	Middle-Income Countries			
Value	14.41	16.20	10.19	12.11
Prob	0.000	0.000	0.000	0.000

Modified DF test statistics that are statistically significant at the 1% level are produced by Model B, in parallel to Model A, spanning the Full Sample Size, LICs, and MICs, providing strong evidence against the null hypothesis that there is no cointegration. This conclusion is further supported by the extremely low p-value of 0.0001, which highlights a high degree of confidence in rejecting the null hypothesis. Similar results are shown by the ADF test, which similarly suggests marginal relevance and shows statistically significant findings at the 1% level. In conclusion, the null hypothesis is consistently rejected by all three statistical tests, suggesting that there may be cointegration among the chosen sampling countries.

The results from the Westerlund (2007) cointegration test provide compelling evidence of potential long-term relationships among the variables analyzed across Sub-Saharan African nations. Both Model A and Model B confirm significant cointegration, implying that changes in one variable are likely to result in corresponding changes in another over time. This suggests interconnectedness and mutual influence among economic sustainability, climate action, national security, and other factors within the region. Policymakers and researchers can leverage these findings to develop targeted strategies and policies that promote sustainable development and economic resilience across diverse national contexts in Sub-Saharan Africa.

4.2 Presentation and Discussion of Empirical Results

The economic sustainability–climate change model, as described in the empirical models in section three, employed variables that have been transformed into logarithmic form. This methodological choice is consistent with the suggestion put forth by Cole et al. (1997), who advocated for the use of logarithmic transformations in model estimation. Recent research, such as Acheampong (2018) and Bouznit and Pablo-Romero (2016), has also adopted this approach when analyzing the relationship between economic sustainability and climate change. Therefore, the empirical estimates presented in this study are derived from the log-linear version of the economic sustainability–climate change model.

TABLE VII: COINTEGRATION RESULTS

	Model A		Model B	
	t-Statistics	p-value	t-Statistics	p-value
Full Sample				
Mod_DF	-2.416	0.008	-2.055	0.019
DF	-3.564	0.000	-3.544	0.000
ADF	-3.4363	0.000	-2.996	0.001
Unadj Mod_DF	-1.079	0.140	-1.548	0.061
Unadj DF	-2.910	0.002	-3.286	0.000
Low Income Countries				
Mod_DF	-1.228	0.109	-1.338	0.091
DF	-1.734	0.042	-2.108	0.018
ADF	-2.573	0.005	-2.511	0.006
Unadj Mod_DF	-0.315	0.376	-0.673	0.251
Unadj DF	-1.211	0.113	-1.743	0.041
Middle-Income Countries				
Mod_DF	-2.674	0.004	-1.467	0.0712
DF	-3.4042	0.0003	-2.242	0.013
ADF	-2.1544	0.016	-0.874	0.191
Unadj Mod_DF	-1.790	0.037	-1.728	0.042
Unadj DF	-3.074	0.001	-2.371	0.009

4.2.1 Interplay of National Security on the Nexus between Economic Sustainability and Climate Action

Based on the preliminary tests, the CCEMG model is expected to provide deeper insights into the relationship between economic sustainability, insecurity, and climate action in Sub-Saharan Africa (SSA) countries. The results of the analysis, conducted across three panels (the full sample, low-income countries (LICs), and medium-income countries (MICs), are presented in Table VIII. The long-run outcomes are presented alongside the short-run estimations at the top half of the table for each of the three panels.

The results from Model A highlight that the level of insecurity (INS) has a significant negative impact on economic sustainability (ES) across the full sample, LICs, and MICs, in both the short-run and long-run. This indicates that higher levels of insecurity lead to a reduction in economic sustainability, with the effect being more pronounced in LICs. The findings suggest that increased insecurity diminishes economic activities, resulting in lower economic sustainability. Rising insecurity in Sub-Saharan Africa poses severe challenges to the region's economies. Insecurity significantly undermines economic sustainability, especially in low-income countries, highlighting the need for improved security measures to bolster economic stability in Sub-Saharan Africa.

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Regarding climate action, the analysis identifies a negative and statistically significant relationship between economic sustainability (ES) and climate change (CC) in the full sample and MICs. This implies that each 1% increase in environmental degradation due to climate change results in a decrease in economic sustainability by 0.09% and 0.01% in the short-run for the full sample and MICs, respectively, and by 0.01% and 0.02% in the long-run for the same groups. Surprisingly, in LICs, the analysis reveals a positive relationship between ES and CC, suggesting that a 1% increase in environmental degradation due to climate change leads to a 0.06% increase in economic sustainability in both the short-run and long-run. While climate change negatively affects economic sustainability in middle-income countries and the overall sample, it surprisingly shows a positive impact in low-income countries, indicating differing regional responses to climate change.

The study finds that gross capital investment (GCI) positively and significantly correlates with economic sustainability (ES) across the full sample, LICs, and MICs, in both the short-run and long-run. This implies that rising capital investment fosters industrial growth and economic sustainability. These findings are consistent with previous research by Baz et al. (2020), Faruq (2019), and Mesagan and Olunkwa (2020), which indicated that capital investment enhances economic performance in regions like Pakistan, Nigeria, and Africa. Additionally, the quality of governance (GEQ) shows a negative relationship with ES in LICs and MICs, with a 1% increase in GEQ leading to decreases in ES by 0.003% and 0.03% in LICs and 0.001% and 0.002% in MICs in the short-run and long-run, respectively. Conversely, in the full sample, GOQ exhibits a positive relationship with ES, where a 1% increase in GEQ results in a 0.005% and 0.004% increase in ES in the short-run and long-run, respectively.

In Model B, climate action that impacts insecurity is integrated into national security to examine its effect on the relationship between economic sustainability and insecurity in Sub-Saharan African (SSA) countries. The results show that insecurity (INS) has a positive short- and long-term impact on economic sustainability (ES) in low-income countries (LICs) and the entire sample. This shows that these regions increased economic sustainability is a result of higher levels of insecurity. Conversely, in middle-income countries (MICs), insecurity negatively impacts economic sustainability in both the short run and long run, indicating that greater insecurity leads to a decline in economic sustainability in these nations. The positive impact of insecurity on economic sustainability in the full sample and LICs might be counterintuitive but could be attributed to several factors. In regions with high insecurity, there might be increased government and international investments aimed at stabilizing the area, which can temporarily boost economic activity. Additionally, informal economic activities might thrive in insecure areas as formal structures break down, contributing to economic figures. However, in MICs, the negative impact of insecurity on economic sustainability is more aligned with traditional economic theory. Insecure environments deter investment, disrupt business operations, and increase costs related to security measures, all of which undermine economic growth and sustainability.

The analysis indicates a positive and statistically significant relationship between economic sustainability (ES) and climate change (CC) in the full sample and LICs. Specifically, a 1% increase in climate change results in a 0.13% rise in economic sustainability in the short run for both the full sample and LICs, and a 0.09% rise in the long run for these groups. However, in MICs, the relationship is negative, with a 1% increase in climate change leading to a decrease in economic sustainability by 0.02% in the short run and 0.03% in the long run. The positive relationship between climate change and economic sustainability in the full sample and LICs could be due to the adaptive measures and green investments that these regions are adopting to combat environmental degradation. Investments in renewable energy, sustainable agriculture, and climate-resilient infrastructure can spur economic activities and growth. For MICs, the negative impact of climate change on economic sustainability is consistent with the broader economic literature. Climate change can lead to increased frequency and severity of natural disasters, loss of agricultural productivity, and higher costs for mitigation and adaptation, all of which can strain economies and reduce their sustainability.

The interactive variable (LNS_CC) exhibits a negative and significant relationship with economic sustainability (ES) in the full sample and LICs in both the short-run and long-run. However, in MICs, LNS_CC shows a positive relationship with economic sustainability in both the short-run and long-run. The interaction between national security and climate change (LNS_CC), showing a negative relationship with economic sustainability in the full sample and LICs, can be explained by the compounded stress that these countries face. In LICs, the dual challenge of maintaining security and addressing climate change can overburden limited resources, leading to inefficiencies and reduced economic performance. Conversely, in MICs, the positive relationship might reflect more robust institutional frameworks and financial capacities to manage these challenges. MICs might be better equipped to leverage national security efforts and climate action into opportunities for innovation, infrastructure development, and attracting foreign investments, thus enhancing economic sustainability.

TABLE VIII: NATIONAL SECURITY ON THE NEXUS BETWEEN ECONOMIC SUSTAINABILITY AND CLIMATE ACTION

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D.LES	Model A		Model B	
	Coef.	Std.Err.	Coef.	Std.Err.
FULL SAMPLE				
ECT	-1.16***	0.049	-1.31***	0.058
Short Run Est.				
INS	-0.001	0.001	0.001	0.001
LCC	-0.093*	0.053	0.133**	0.057
LGCI	0.011	0.025	0.031*	0.019
GEQ	0.005	0.004	-0.001	0.002
LNS_CC			-0.067***	0.021
Long Run Est.				
INS	-0.01	0.001	0.001	0.001
LCC	-0.071	0.048	0.089**	0.042
LGCI	0.01	0.023	0.016	0.017
GEQ	0.004	0.004	-0.002	0.002
LNS_CC			-0.048***	0.015
LOW INCOME COUNTRIES				
ECT	-1.165***	0.073	-1.322***	0.068
Short Run Est.				
INS	-0.002	0.002	0.001	0.002
LCC	0.06	0.05	0.13**	0.062
LGCI	0.04**	0.018	0.043*	0.025
GEQ	-0.003	0.004	-0.001	0.003
LNS_CC			-0.078***	0.030
Long Run Est.				
INS	-0.003	0.002	0.002	0.002
LCC	0.056	0.054	0.091*	0.048
LGCI	0.03*	0.016	0.034*	0.018
GEQ	-0.002	0.003	-0.001	0.002
LNS_CC			-0.053**	0.022
MIDDLE INCOME COUNTRIES				
ECT	-1.26***	0.074	-1.34***	0.091
Short Run Est.				
INS	-0.001	0.001	-0.001	0.001
LCC	-0.004	0.058	-0.022	0.071
LGCI	0.003**	0.035	0.055**	0.045
GEQ	-0.001	0.002	-0.002	0.002
LNS_CC			0.013	0.043
Long Run Est.				
INS	- 0.001	0.001	-0.001	0.001
LCC	-0.019*	0.048	-0.03	0.052
LGCI	0.003	0.029	0.028	0.031
GEQ	-0.002	0.002	-0.003	0.002
LNS_CC			0.016*	0.029

Source: Author's Computation using Stata 15 (2024) Note: *p < 0.1, **p < 0.05, ***p < 0.01

5 CONCLUSION

The analysis of economic sustainability, insecurity, and climate action in Sub-Saharan African countries reveals several significant implications. Insecurity significantly undermines economic sustainability, particularly in low-income countries, which underscores the critical need for policies and interventions focused on enhancing security to foster a stable environment conducive to economic growth. The study also highlights the general negative influence of climate change on economic sustainability in Sub-Saharan African countries, especially in middle-income nations. However, the positive impact observed in low-income countries suggests that these regions may be implementing adaptive strategies or experiencing temporary economic benefits from climate-related investments.

Capital investment emerges as a vital driver of economic sustainability across all country groups, highlighting the importance of creating a favorable investment climate, offering financial incentives, and ensuring political stability to attract and sustain investments. Governance quality has varied effects on economic sustainability, enhancing it in the overall sample but negatively impacting low- and middle-income countries. This suggests that, despite the importance of good governance practices, targeted governance reforms and capacity-building efforts are needed in LICs and MICs to translate good governance into economic benefits.

The interaction between national security and climate action presents complex dynamics. In highly insecure regions, targeted security measures might lead to temporary economic improvements, whereas in more stable middle-income countries, insecurity has a clear detrimental effect. This underscores the need for integrated policies that address both security and climate resilience comprehensively. These findings emphasize the necessity for tailored policy interventions to address the unique challenges faced by different country groups within Sub-Saharan Africa, aiming

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to enhance economic stability and sustainability in the face of insecurity and climate change.

Based on the above findings, the following recommendations are proposed:

i. In Sub-Saharan Africa (SSA) countries, the Ministries of Defense, the Ministries of Police Affairs, and the other relevant security departments in each country should be integrated into the Committee on Climate Action and Green Economic

ii. Academic curricula used in various Defense and Police Academies in SSA countries must be revised to incorporate the climate-security nexus to equip upcoming officers to handle security risks resulting from climate change.

iii. To build the necessary capacity to effectively incorporate climate considerations into security procedures, specific training programs concentrating on climate risk assessments, early warning systems, and climate-resilient operations should be developed for major security agencies in SSA countries.

iv. Governments should prioritize policies that encourage green technology and practices that will help mitigate the detrimental impacts of climate change on economic sustainability.

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