



# Climate Change, Institutional Quality, and Inclusive Growth in Sub-Saharan Africa

David Igbadoo Anum, Abdulkareem Alhassan, Eko Omini Eko

Department of Economics, Faculty of Social Sciences, Federal University Lafia, Nasarawa State, Nigeria

DOI: <https://doi.org/10.68050/JAMS.2026.241>

Received: 30 Aug 2026; Accepted: 01 Sept 2026; Published: 23 September 2026

## ABSTRACT

Climate shocks increasingly endanger Sub-Saharan Africa's economic trajectory, disproportionately impacting the region's agricultural and resource-reliant nations. To investigate these dynamics, this research analyzes a balanced panel data-set of 16 Sub-Saharan African economies spanning 2010 through 2025, exploring the interplay between environmental pressures, institutional frameworks, and inclusive growth. Utilizing a dynamic panel auto-regressive distributed lag methodology, the analysis evaluates whether governance quality captured via a composite metric derived from the World Governance Indicators buffers the adverse impacts of environmental stress on income disparity and poverty levels. The empirical evidence indicates that while ecological degradation undermines inclusive advancement, robust institutional structures significantly mitigate or even neutralize these negative consequences. Ultimately, the findings emphasize that high-quality governance serves as a vital safeguard against climate vulnerabilities, highlighting that successful climate finance initiatives must be coupled with structural governance reforms to safeguard marginalized populations and achieve the Sustainable Development Goals.

**Keywords:** Climate Change; Institutional Quality; Inclusive Growth; Sub-Saharan Africa; Panel ARDL; Environmental Resilience; Moderation Effects.

## INTRODUCTION

Sub-Saharan Africa occupies a precarious developmental crossroad, balancing the imperative for economic expansion against escalating ecological disruption. Although the region possesses abundant natural resources, this wealth has largely failed to generate widespread improvements in human well-being a structural dynamic characterized here as the "vulnerability trap." This trap is manifested through increasingly volatile precipitation patterns, persistent droughts in the Horn of Africa, and severe flooding events that undermine food and energy security while jeopardizing the livelihoods of populations reliant on climate-vulnerable sectors like smallholder agriculture and artisan fishing [1, 2].

The distribution of these environmental shocks is heavily mediated by domestic institutional capacity. Emerging empirical literature indicates that robust governance characterized by bureaucratic efficiency, adherence to the rule of law, and effective regulatory frameworks enhances adaptive capacity and mitigates ecological degradation [3, 4]. Conversely, institutional fragility impairs policy implementation, heightening the exposure of vulnerable demographics and reinforcing persistent poverty cycles [4, 5]. Consequently, institutional quality functions beyond mere background conditions; it acts as a decisive mechanism determining whether economic growth can successfully decouple from environmental hazards [6, 7].

Despite these insights, a substantial empirical void persists regarding the joint trajectory of climate pressures, economic growth, and governance structures between 2010 and 2025 an interval characterized by unprecedented meteorological instability, evolving global climate finance frameworks, and geopolitical disruptions that strained state administrative capacities across Sub-Saharan Africa. The prevailing literature largely evaluates institutions, economic performance, and environmental indicators in isolation, leaving a paucity of empirical investigations that explicitly test institutional quality as a moderating force within the climate-growth nexus across this turbulent contemporary era.



This omission carries critical policy implications, as macroeconomic aggregates often obscure profound and entrenched vulnerabilities. Consequently, the core empirical inquiry of this research interrogates why numerous Sub-Saharan African economies continually fail to protect their most vulnerable populations from environmental shocks despite maintaining positive headline growth rates. Framed through this lens, the investigation examines whether institutional reinforcement can break the causal chain linking climate volatility to poverty, and whether robust governance can prevent environmental instability from derailing advancement toward the Sustainable Development Goals.

To address these questions, the study undertakes a cross-country panel analysis of sixteen Sub-Saharan African economies, chosen to reflect the region's socio-economic diversity, over 2010-2025. The analysis centers on whether institutional quality - a composite index built through principal component analysis (PCA) from six World Governance Indicators (government effectiveness, rule of law, control of corruption, regulatory quality, voice and accountability, and political stability) - moderates the relationship between environmental stress (captured by temperature anomalies and CO<sub>2</sub> emissions) and inclusive growth (captured by poverty reduction and income-equality metrics). Three objectives follow: first, to estimate the direct long-run effect of climate change on inclusive development in Sub-Saharan Africa; second, to estimate the effect of institutional quality on the same outcome; and third, to test - through the interaction of climate stress and institutional quality - whether strong governance shields economies from climate-induced setbacks and supports a more resilient growth path.

## **LITERATURE REVIEW**

### **Conceptual Clarification**

#### **Climate Change**

Climate change denotes long-term shifts in weather patterns driven jointly by natural variability and human activity [8, 9]. The burning of fossil fuels is the principal driver of global warming, raising atmospheric greenhouse-gas concentrations and disrupting environmental systems worldwide [10].

#### **Institutional Quality**

Institutional quality refers to the reliability of a country's legal and administrative apparatus, commonly proxied by indicators such as the rule of law and control of corruption [11]. Strong institutions reduce transaction uncertainty and protect property rights, both prerequisites for long-horizon investment and planning [12]; in this sense, the consistency and integrity of governance underpin sustained economic prosperity [12].

#### **Inclusive Growth**

Inclusive growth extends beyond the sheer rate of economic expansion to encompass the equitable distribution of its gains across society [13]. Rather than relying solely on post-market redistribution, it prioritizes broad-based economic participation, targeted employment generation for marginalized groups, and structural transformation [13, 14]. Key mechanisms for achieving this include lowering barriers to market entry, boosting human capital investments, and strengthening social protection systems [15, 16]. Integrating a larger share of the labor force into the formal economy fosters long-term stability and sustainable development [17], while ensuring that prosperity is widely shared rather than captured by a narrow socioeconomic elite [18].

### **The Climate-Institution-Growth Nexus**

Institutional quality fundamentally conditions an economy's capacity to absorb climate-induced volatility [19, 20]. Inclusive institutional frameworks tend to direct capital toward long-term resilience-building investments, whereas extractive structures prioritize short-term rent extraction over long-run structural stability [19, 21]. In many developing nations, institutional deficits within legal and fiscal mechanisms constrain the adaptive capacity of agricultural sector infrastructure and public finance systems facing climate disruptions [19].



Consequently, achieving sustainable economic trajectories relies heavily on governance architectures sufficiently robust to withstand ongoing environmental stress [20].

### **Theoretical Review**

The theoretical literature predominantly frames governance as the critical determinant governing Sub-Saharan Africa's capacity to translate climate resilience into inclusive advancement. From this perspective, the region's susceptibility to ecological shocks is driven more by the efficacy of its formal and informal regulatory frameworks than by inherent geographical vulnerabilities.

### **New Institutional Economics**

Grounded in New Institutional Economics, this study posits that a society's foundational "rules of the game" are critical determinants of its economic trajectory [11]. Within the context of Sub-Saharan Africa, this theoretical perspective illuminates why nations exposed to comparable climatic stressors exhibit divergent socio-economic outcomes [21]. Generally, inclusive institutions demonstrate a superior capacity to deploy effective climate adaptation strategies, whereas extractive structures exacerbate structural vulnerabilities and hinder adaptive measures [19]. Consequently, a significant proportion of the economic losses conventionally attributed to climate shocks can be understood as institutional failures in safeguarding vulnerable sectors [20]. Enhancing governance capacity thus emerges as an indispensable prerequisite for insulating economies against environmental instability [11, 19].

### **The Environmental Kuznets Curve (EKC) Hypothesis**

The analytical framework further incorporates the Environmental Kuznets Curve (EKC) hypothesis to evaluate how institutional quality moderates the nexus between economic expansion and ecological degradation across Sub-Saharan Africa [22, 23]. While the conventional EKC posits an inverted U-shaped trajectory whereby environmental degradation initially intensifies with early-stage growth before eventually declining past a specific income threshold pervasive institutional fragility frequently traps regional economies below this critical turning point. Consequently, the empirical investigation evaluates whether robust governance facilitates the transition across the EKC threshold, exploring the structural mechanisms that leave certain nations confined within a high-pollution, low-growth equilibrium. Section 4.5 expands upon this dynamic, demonstrating that institutional strength is a fundamental determinant governing both the timing and the feasibility of this structural transition.

### **The Capability Approach**

Building further upon Amartya Sen's capability approach, this investigation redirects its evaluative lens away from narrow GDP expansion toward the broader enhancement of human freedoms and fundamental capabilities. Within Sub-Saharan Africa, climate-induced food insecurity directly erodes these foundational capabilities, highlighting the crucial protective function that domestic institutions perform. Anand et al. [17] conceptualize institutions as dual economic and moral safeguards for vulnerable populations; when these systems collapse, marginalized groups shoulder the heaviest burdens regardless of aggregate macroeconomic performance. Consequently, institutional quality remains paramount for shielding human development outcomes from climate-driven disruptions.

### **Empirical Review**

Nginyu et al. [24] investigate the interactive effects of governance and bio-capital on inclusive human development across thirty-nine Sub-Saharan African economies. Employing a System Generalized Method of Moments (GMM) framework, the research transcends traditional income-centric development metrics, though the empirical estimates remain susceptible to slope heterogeneity and cross-sectional dependence. The primary empirical conclusion indicates that bio-capacity drives development predominantly via health-related pathways, alongside unexpected inverse correlations between trade, foreign direct investment, and development outcomes that the study identifies as requiring deeper scholarly inquiry.



Afolabi and Oyeleke [25] evaluate the nexus between institutional quality and inclusive growth across twenty-nine Sub-Saharan African nations spanning 1996 through 2021 utilizing a Panel Auto-regressive Distributed Lag methodology. The findings establish that governance frameworks foster long-run economic expansion, with political stability exerting a distinct short-run influence. Nevertheless, the theoretical framework lacks explicit mapping between specific governance indicators and growth trajectories, and the utilization of ranked multiple proxies obscures precise interpretation; furthermore, the omission of corrections for cross-sectional dependence limits the robustness of the estimations.

Abdul-Karim and Alabani [26] analyze climate finance within Sub-Saharan Africa through an institutional and development-economics perspective, contending that robust regulatory and administrative frameworks are prerequisites for the effective utilization of climate adaptation funds. However, the empirical analysis reveals only a weak statistical correlation between climate finance allocations and measurable decreases in poverty and inequality suggesting that capital inflows in isolation cannot achieve socio-economic inclusion absent complementary institutional reforms that account for regional heterogeneity, demographic shifts, and governance capacity.

Oyelami et al. [27] investigate the interactions among climate change, institutional quality, and food security across twenty-six nations utilizing Cross-Sectionally Augmented Auto-regressive Distributed Lag (CS-ARDL) estimation. While climatic factors prove to be robust determinants of food insecurity, institutional quality registers as statistically insignificant a finding that diverges from standard theoretical expectations. Although the econometric approach effectively accounts for cross-sectional dependence, the reliance on aggregate World Governance Indicators potentially masks more nuanced, dis-aggregated institutional dynamics, an analytical constraint the study acknowledge.

These positive-moderation findings are not universal, however, and two recent studies illustrate why the present paper treats the CC×IQ result as an empirical question rather than a foregone conclusion. Okere and Fasanya [34], examining fossil-fuel consumption, technological progress, and environmental sustainability across Central and Southern African economies (1996-2021), find that institutional quality has no statistically significant effect on environmental outcomes once fossil-fuel dependence and technological progress are controlled for a direct null result for the institutional-buffering hypothesis this paper tests. Similarly, Chamma [35], integrating corruption, political instability, and climate stress into a System-GMM model of economic growth across forty-three Sub-Saharan African countries (1996-2019), reports that strong institutions improve resilience but cannot fully offset the economic costs of rising temperatures, and that corruption and political instability actively erode climate governance and intensify emissions - positioning institutions as simultaneously a buffer and a source of vulnerability rather than a clean moderating force. Read alongside Oyelami et al. [27] and Bambi et al. [29] above, these studies suggest that the strength, and even the sign, of institutional moderation is sensitive to country coverage, time period, and how institutional quality is measured. This heterogeneity across contrasting recent studies motivates the alternative-measure and alternative-estimator robustness checks reported in Section 4.7.1 below, rather than relying on the single PCA-composite IQ index and single estimator used in the baseline specification.

Acheampong and Dzator [28] examine the linkage between governance structures and carbon emissions across forty-five Sub-Saharan African economies via a system-GMM methodology. While controlling for diverse macroeconomic and energy-related drivers, the model initially presumes homogenous institutional impacts across the region. Furthermore, the study links a significant proportion of mitigation performance differentials to historical colonial origins, offering limited scope to analyze governance frameworks outside the context of British and French colonial legacies a methodological limitation requiring supplementary qualitative analysis.

Bambi et al. [29] challenge the conventional interchangeability of governance and institutional quality, demonstrating that formal institutional strength can paradoxically expand ecological footprints in Sub-Saharan Africa under conditions of weak enforcement and systemic corruption. Employing dynamic panel estimators, the study detect an inverted-U relationship wherein genuine governance effectiveness ultimately counteracts the negative externalities associated with nominal institutional structures. Nevertheless, the twenty-five-country sample size imposes constraints on statistical power and causal identification, prompting the

recommendation for comprehensive, energy-targeted institutional restructuring over fragmented legislative measures to escape the regional pollution-growth trap.

Alkali et al. [30] investigate the structural barriers inhibiting climate-responsive residential architecture in northeast Nigeria. Although the classification of professional and socio-cultural obstacles offers valuable qualitative insights, the cross-sectional design prevents any causal linkage between subjective stakeholder assessments and longitudinal building energy performance, nor does it control for interstate disparities in policy enforcement leaving unresolved whether the identified constraints are structural or merely reflective of local regulatory and educational deficits. This methodological limitation underscores a compelling research opportunity centered on integrating formal institutional governance metrics with objective performance datasets.

Omri et al. [4], alongside Olabanji and Chitakira [31] and Subramaniam et al. [32], analyze the climate-governance-growth nexus within Sub-Saharan Africa utilizing aggregated indices that frequently obscure informal institutional dynamics and remain susceptible to endogeneity. Collectively, this body of literature documents a governance-mediated vulnerability trap yet yields conflicting conclusions regarding whether institutional effectiveness can remain self-sustaining without concurrent fiscal backing. A persistent empirical void involves how localized conflict moderates the transmission channels between climate finance and sub-national economic performance; integrating micro-level, conflict-sensitive, and gender-dis-aggregated data represents a vital pathway for future inquiry.

Earlier foundational investigations by Mesagan and Eregha [33] established a baseline link between institutional quality and poverty alleviation, but predate the severe meteorological anomalies observed over the past decade. Conversely, UNECA [2] emphasizes that recent climatic shocks have fundamentally altered regional governance trajectories. By conceptualizing institutional quality as a moderating mechanism between environmental stress and inclusive growth across the 2010-2025 observation window, this study directly bridges these empirical gaps, rigorously testing whether strengthened institutional architectures can successfully decouple economic advancement from ecological vulnerability.

Synthetically, existing scholarship indicates that robust institutional frameworks can function as a crucial protective buffer against the socio-economic pressures unleashed by climate change. The selection of the 2010-2025 study window is intentional, capturing an exceptionally intense period of climatic volatility and governance disruption that acts as a natural econometric stress test for the variables under review. To formalize this conceptual intuition, the research incorporates a climate-institutional quality interaction term within the Panel Auto-regressive Distributed Lag framework, shifting the empirical analysis beyond mere correlation toward a precise, parameter driven evaluation of whether and to what quantitative extent governance moderates the long-run developmental fallout of environmental stress.

## METHODOLOGY

### Data Sources

The empirical analysis utilizes a balanced annual panel data-set spanning sixteen (16) Sub-Saharan African economies from 2010 to 2025, compiled from authoritative repositories including FAOSTAT, the World Bank, PovcalNet, and the World Inequality Database. The data-set integrates environmental metrics, an institutional quality index constructed via principal component analysis (PCA), and a composite index of inclusive growth, supplemented by essential macroeconomic controls such as real GDP per capita, foreign direct investment, and gross capital formation. The complete country selection and panel balancing specifications are detailed in Appendix A. Table 1 presents the principal component analysis weights utilized to construct the Climate Change (CC) index. Furthermore, adhering to standard econometric reporting protocols, Table 2 structures the variables according to their functional classification within the empirical model distinguishing between dependent, independent, and control variables rather than relying on thematic categorizations.

The sixteen countries were selected using three criteria: (i) uninterrupted annual data availability for 2010-2025 across all FAOSTAT, World Bank, PovcalNet, and World Inequality Database series required to

construct the CC, IQ, and IG indices, which excluded several economies with recurring data gaps; (ii) representation across the region's five sub-regional blocs (West, East, Central, Southern, and the Horn of Africa), so that no single sub-region dominates the panel; and (iii) deliberate inclusion of countries spanning the institutional-quality distribution from comparatively strong governance performers such as Botswana, Mauritius, and Rwanda to lower-scoring economies such as Angola, Mozambique, and Cameroon to ensure sufficient variation in IQ for identifying the CC×IQ interaction. Table A2 (Appendix A) reports each country's average institutional-quality score alongside its sub-regional classification, confirming that the sample spans low-, middle-, and high-institutional-quality contexts rather than clustering around a single governance profile. This selection strategy necessarily favors larger, more data-complete economies over smaller or more data-scarce ones, a trade-off revisited as a limitation in Section 5.3.

### Construction of the Climate Change (CC) Index

The Climate Change (CC) index is constructed using a methodology analogous to the institutional-quality index, drawing upon two foundational raw series: the annual mean temperature anomaly (measured as a degrees Celsius deviation from the 1981-2010 climatology baseline, sourced from FAOSTAT) and per capita carbon dioxide emissions in metric tons (from the World Bank World Development Indicators). Both series are standardized into z-scores and synthesized into a unified composite metric via principal component analysis (PCA). The first principal component (PC1) is extracted, with its underlying variance structure detailed below.

**Table 1: Principal Component Analysis Summary for the Climate Change Index**

| Component   | Eigenvalue | Difference | Proportion | Cumulative |
|-------------|------------|------------|------------|------------|
| PC1 (Comp1) | 1.3452     | 0.6904     | 0.6726     | 0.6726     |
| PC2 (Comp2) | 0.6548     | -          | 0.3274     | 1.0000     |

**Note:** Number of observations = 256 (16 countries over 2010-2025); number of components = 2. Variables included: standardized annual mean temperature anomaly and standardized per-capita CO<sub>2</sub> emissions.

**Source:** Author's computation using Stata 17, 2026.

Elevated values of the CC index signify heightened environmental pressure, manifested through more severe temperature anomalies or greater emission intensities. This methodological design mirrors the principal component analysis applied to construct the Institutional Quality (IQ) index from the underlying World Governance Indicators, ensuring that both composite metrics share a standardized, unit-free scale. The IQ index itself is synthesized from six distinct World Governance Indicators government effectiveness, rule of law, control of corruption, regulatory quality, voice and accountability, and political stability aggregated via PCA. Crucially, government effectiveness and the rule of law are not modeled as independent, dis-aggregated coefficients; rather, they serve as foundational inputs feeding directly into the unified IQ index detailed in Table 2 below.

**Table 2: Variable Definitions and Data Sources**

| Variable Role        | Variable Name          | Symbol | Description                                                          | Data Source           |
|----------------------|------------------------|--------|----------------------------------------------------------------------|-----------------------|
| Dependent Variable   | Inclusive Growth       | IG     | Composite index of poverty/inequality (PCA)                          | PovcalNet / WID       |
| Independent Variable | Climate Change         | CC     | PCA composite of temperature anomalies and CO <sub>2</sub> emissions | FAOSTAT / WDI         |
| Independent Variable | Institutional Quality  | IQ     | PCA composite of six WGI dimensions                                  | World Bank (WGI)      |
| Interaction Term     | Climate × Institutions | CC×IQ  | Product of mean-centered CC and IQ                                   | Author's construction |
| Control Variable     | Real GDP per           | RGDP   | Log of real GDP per capital                                          | World Bank            |



|                  |                           |     |                                          |                  |
|------------------|---------------------------|-----|------------------------------------------|------------------|
|                  | capita                    |     |                                          | (WDI)            |
| Control Variable | Foreign Direct Investment | FDI | Net inflows (% of GDP)                   | World Bank (WDI) |
| Control Variable | Gross Capital Formation   | GCF | Gross fixed capital formation (% of GDP) | World Bank (WDI) |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capita, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

Table 2 sets out the definition, measurement, and source of each variable used in the analysis, including the climate  $\times$  institutional-quality interaction term introduced to test moderation directly (Section 3.2).

### Missing Data and Panel Balancing

Of the 4,096 country-year-series cells underlying the balanced panel (16 countries  $\times$  16 years  $\times$  16 raw series feeding the CC, IQ, and IG composites), 187 cells (4.6 percent) were missing in their originally reported form. Gaps were concentrated in two places: the earlier years (2010-2012) of the World Governance Indicators for Angola and Mozambique, where WGI coverage of some sub-components began only in 2011-2012, and the PovcalNet/WID poverty and inequality series for Ethiopia and Zambia, which are reported at irregular survey intervals rather than annually.

Missing values were treated as follows. First, gaps of one or two consecutive years within an otherwise complete country series were filled by linear interpolation between the nearest observed years; this accounted for 141 of the 187 missing cells (75.4 percent). Second, gaps at the very start of a series (2010 for a small number of WGI sub-indicators) were filled using the nearest available observation, carried backward; this accounted for a further 31 cells (16.6 percent). Third, the remaining 15 cells (8.0 percent), concentrated in early-year FDI data for two countries, were filled using the country's own five-year trailing average up to that point, since neither interpolation nor carry-forward was available at the start of the panel. No country-year was dropped outright: every gap was resolved through one of these three procedures, which is what allows the panel to remain balanced ( $T = 16$  for all 16 countries) rather than requiring an unbalanced-panel estimator.

To confirm that these imputations do not drive the results, the long-run Panel ARDL model in Table 10 was re-estimated on the sub-sample of country-years with no imputed values in any series (208 of the 256 observations are fully observed across all seven variables). The sign, magnitude, and statistical significance of the climate change, institutional quality, and CC $\times$ IQ coefficients are materially unchanged relative to the full-sample estimates (CC $\times$ IQ = 0.301,  $p < 0.01$ , versus 0.315 in the full sample), indicating that the imputation procedure is not responsible for the paper's central moderation finding.

### Model Specification

The empirical investigation models the dynamic interplay among climate change, institutional quality, and economic growth utilizing a Panel Auto-regressive Distributed Lag (ARDL) framework. This econometric approach is particularly well-suited for the research objectives as it simultaneously captures long-run equilibrium relationships and short-run adjustment dynamics, while gracefully accommodating the sluggish temporal evolution characteristic of institutional structures. The error-correction representation of the Panel ARDL specification is formulated below, maintaining strict consistency with the variable notation established in Table 2.

$$\Delta IG_{it} = \varphi_i(IG_{i,t-1} - \beta_1 CC_{i,t-1} - \beta_2 IQ_{i,t-1} - \beta_6(CC \times IQ)_{i,t-1} - \beta_3 RGDP_{i,t-1} - \beta_4 FDI_{i,t-1} - \beta_5 GCF_{i,t-1}) + \sum \gamma_{ij} \Delta IG_{i,t-j} + \sum \delta_{ij} \Delta CC_{i,t-j} + \sum \phi_{ij} \Delta IQ_{i,t-j} + \sum \theta_{ij} \Delta (CC \times IQ)_{i,t-j} + \sum \eta_{ij} \Delta Z_{i,t-j} + \varepsilon_{it} \text{-----}(1).$$

where Z denotes the vector of control variables (RGDP, FDI, GCF), and CC $\times$ IQ is the mean-centered product of CC and IQ, included to test whether institutional quality moderates the climate-growth relationship.

**Table 3: Variable Role Mapping**

| Variable Role | Symbol         | Description                                                             |
|---------------|----------------|-------------------------------------------------------------------------|
| Dependent     | IG             | Inclusive Growth (composite index)                                      |
| Independent   | CC, IQ         | Climate Change (CO <sub>2</sub> /temperature) and Institutional Quality |
| Moderation    | CC×IQ          | Interaction term testing whether IQ moderates the CC→IG relationship    |
| Control       | RGDP, FDI, GCF | Real GDP (log), Foreign Direct Investment, and Gross Capital Formation  |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

Table 3 reclassifies the variables from Table 2 based on their specific econometric functions within Equation (1), moving away from thematic categorization. This methodological distinction is crucial because the core moderation hypothesis relies on estimating the CC X IQ interaction term as a distinct, unified regressor separate from its constituent main effects (CC and IQ). Furthermore, isolating the macroeconomic control variables (RGDP, FDI, GCF) ensures they adequately account for standard economic drivers of inclusive growth, allowing the coefficients for CC, IQ, and their interaction to cleanly capture the primary substantive relationships analyzed in Sections 4.5 and 4.8.

### The Co-integrating Equation and Error Correction Model

The long-run co-integrating relationship, normalized on the dependent variable IG and augmented with the climate × institutional-quality interaction term, is expressed as:

$$IG_t = \beta_0 + \beta_1 CC_t + \beta_2 IQ_t + \beta_6(CC \times IQ)_t + \beta_3 RGDP_t + \beta_4 FDI_t + \beta_5 GCF_t + \varepsilon_t \text{ -----(2).}$$

Rearranging this expression gives the error correction term (ECT), which measures the deviation of inclusive growth from its long-run equilibrium in the previous period:

$$ECT_{t-1} = IG_{t-1} - (\beta_0 + \beta_1 CC_{t-1} + \beta_2 IQ_{t-1} + \beta_6(CC \times IQ)_{t-1} + \beta_3 RGDP_{t-1} + \beta_4 FDI_{t-1} + \beta_5 GCF_{t-1}) \text{ -----(3).}$$

The full error correction model then incorporates this term to capture the speed of adjustment toward long-run equilibrium:

$$\Delta IG_t = \alpha_0 + \sum \gamma_i \Delta IG_{t-i} + \sum \delta_{1i} \Delta CC_{t-i} + \sum \delta_{2i} \Delta IQ_{t-i} + \sum \delta_{6i} \Delta (CC \times IQ)_{t-i} + \sum \delta_{3i} \Delta RGDP_{t-i} + \sum \delta_{4i} \Delta FDI_{t-i} + \sum \delta_{5i} \Delta GCF_{t-i} + \lambda ECT_{t-1} + \mu_t \text{ -----(4).}$$

Here, the  $\Delta$  operator captures short-run fluctuations - the immediate effect of climate, institutions, and macroeconomic conditions on inclusive growth, net of the long-run equilibrium already captured by the ECT. The coefficient on the lagged error correction term,  $\lambda$ , measures the speed of adjustment: a negative  $IG / CC = \beta_1 + \beta_6 \cdot IQ$ .

and significant  $\lambda$  indicates that the system returns toward equilibrium after a shock, closing part of the previous period's disequilibrium - for instance, a drought-induced decline in growth relative to trend.

The coefficient  $\beta_6$  on  $CC \times IQ$  directly tests the moderation claim set out in the abstract. The marginal impact of climate change on inclusive growth is expressed as  $\delta IG / \delta CC = \beta_1 + \beta_6 \cdot IQ$ . Consequently, a positive coefficient for  $\beta_6$  indicates that higher institutional quality mitigates the adverse developmental consequences of environmental stress, supporting the decoupling framework detailed in Section 4.5. This structural relationship establishes why the interaction term rather than the isolated main effects serves as the definitive test for moderation.

Simultaneously, endogeneity presents a critical econometric challenge, as institutional quality (IQ) and inclusive growth (IG) exhibit simultaneous feedback: improved socio-economic outcomes can elevate demands for robust governance, while exogenous shocks may simultaneously impact both series. This induces reverse causality and creates potential bias in the  $\beta_2$  and  $\beta_6$  estimators within Equation (2). To mitigate this vulnerability, Section 4.7 employs a System-GMM and instrumental variables specification utilizing contemporaneous IQ instrumented by its first and second lags. While this offers a valuable robustness check confirming the sign and statistical significance of the governance coefficient, establishing reliable instrument strength remains inherently challenging within a compressed panel of sixteen countries.

## RESULTS AND DISCUSSION

### Descriptive Overview

**Table 4: Regional Indicators for Sub-Saharan Africa, Annual Estimates (2010-2025)**

| Year | RGDP (Annual % Growth) | CO <sub>2</sub> (Metric Tons/Capita) | GINI (Proxy Index) | FDI (% of GDP) | GCF (% of GDP) |
|------|------------------------|--------------------------------------|--------------------|----------------|----------------|
| 2010 | 4.6                    | 0.79                                 | 50.1               | 2.5            | 22.1           |
| 2011 | 3.9                    | 0.8                                  | 50.45              | 2.6            | 22.4           |
| 2012 | 4.3                    | 0.81                                 | 50.8               | 2.8            | 22.8           |
| 2013 | 4.1                    | 0.82                                 | 51.15              | 2.7            | 23.1           |
| 2014 | 4                      | 0.82                                 | 51.5               | 2.6            | 23.5           |
| 2015 | 3                      | 0.78                                 | 51.8               | 2.4            | 22.2           |
| 2016 | 1.5                    | 0.75                                 | 52.1               | 2.2            | 21             |
| 2017 | 2.5                    | 0.74                                 | 52.45              | 2.1            | 20.7           |
| 2018 | 2.8                    | 0.73                                 | 52.8               | 2.1            | 20.5           |
| 2019 | 2.6                    | 0.71                                 | 52.9               | 1.8            | 20.1           |
| 2020 | -3                     | 0.66                                 | 53                 | 1.5            | 19.8           |
| 2021 | 4.1                    | 0.68                                 | 53.1               | 2.2            | 20             |
| 2022 | 3.9                    | 0.7                                  | 53.2               | 2.4            | 20.2           |
| 2023 | 3.6                    | 0.7                                  | 53.3               | 2.3            | 20.3           |
| 2024 | 3.5                    | 0.7                                  | 53.4               | 2.3            | 20.5           |
| 2025 | 3.1                    | 0.71                                 | 53.44              | 2.3            | 20.6           |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation. GINI (Proxy Index) is a PovcalNet/WID-derived proxy for income inequality, re-scaled 0-100, that feeds into the IG composite alongside the poverty headcount ratio; it is not the raw World Bank Gini coefficient.

**Source:** Author's computation using Stata 17, 2026.

### Interpretation of Regional Trends (2010-2025)

**Real Gross Domestic Product (RGDP):** Economic expansion exhibited persistent volatility, commencing at a robust 4.6% in 2010 before decelerating, toughing at -3.0% during the 2020 global pandemic crisis, and eventually rebounding to stabilize near 3.1% by the terminal year of 2025.

**Per Capita Carbon Emissions (CO<sub>2</sub>):** Environmental stress indicators remained minimal across the time-frame, reaching a high of 0.82 metric tons in 2013-2014, contracting through economic downturns, and ascending incrementally to 0.71 metric tons by 2025.



Income Inequality (GINI Proxy): Structural income disparities demonstrated a consistent upward drift, climbing from 50.10 in 2010 to 53.44 in 2025, underscoring that equitable wealth distribution remained a structural bottleneck despite periods of macroeconomic recovery.

Capital Formation and Investment Inflows: Both foreign direct investment (expressed as a percentage of GDP) and gross capital formation experienced sharp contractions during the 2020 shock dipping to 1.5% and 19.8%, respectively prior to staging a gradual recovery toward pre-exist baselines by 2025.

**Table 5: Descriptive Statistics**

| Variable | Mean   | Std. Dev. | Min   | Max   | N   |
|----------|--------|-----------|-------|-------|-----|
| IG       | 42.158 | 8.421     | 21.3  | 68.45 | 256 |
| CC       | 0.042  | 0.985     | -2.41 | 2.85  | 256 |
| IQ       | -0.215 | 0.673     | -1.89 | 1.42  | 256 |
| RGDP     | 3.245  | 2.185     | -6.5  | 10.8  | 256 |
| FDI      | 2.41   | 1.95      | -0.45 | 14.2  | 256 |
| GCF      | 22.84  | 6.12      | 8.1   | 45.6  | 256 |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital growth, FDI = Foreign Direct Investment (% of GDP), GCF = Gross Capital Formation (% of GDP). Computed on the balanced panel of Sub-Saharan African countries (N = 16 countries over T = 16 years, 2010-2025, total observations = 256).

**Source:** Author's computation using Stata 17, 2026.

Table 5 indicates substantial cross-sectional and temporal heterogeneity in inclusive growth (IG), spanning from 21.300 to 68.450, thereby reflecting the region's uneven performance in converting aggregate macroeconomic expansion into broad-based societal welfare improvements. Although the Climate Change (CC) index is standardized around a mean near zero, its dispersion (SD= 0.985) and broad minimum-to-maximum interval (-2.410 to 2.850) demonstrate significant cross-country and longitudinal variation in environmental stress providing the empirical variation necessary for the Panel ARDL framework to identify the parameters  $\beta_1$  and  $\beta_6$ . Institutional quality (IQ) exhibits a negative sample mean (-0.215), mirroring well-established governance deficits across Sub-Saharan Africa, though a peak value of 1.420 highlights that specific country-years attain higher institutional benchmarks. Finally, the control variables display standard deviations proportionate to their respective means, confirming the absence of extreme outliers that might otherwise bias the long-run estimations reported in Table 10.

**Table 6: Pairwise Correlation Matrix**

| Variables | IG        | CC      | IQ        | RGDP      | FDI |
|-----------|-----------|---------|-----------|-----------|-----|
| IG        | 1         | -       | -         | -         | -   |
| CC        | 0.1842*   | 1       | -         | -         | -   |
| IQ        | 0.5412*** | 0.0921  | 1         | -         | -   |
| RGDP      | 0.3210*** | -0.0415 | 0.2840*** | 1         | -   |
| FDI       | 0.2150**  | 0.052   | 0.3120*** | 0.4150*** | 1   |

|     |           |       |           |           |           |
|-----|-----------|-------|-----------|-----------|-----------|
| GCF | 0.4520*** | 0.123 | 0.3850*** | 0.5120*** | 0.3940*** |
|-----|-----------|-------|-----------|-----------|-----------|

**Note:** Asterisks denote significance: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Coefficients computed across the full panel ( $N = 256$ ). IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

Table 6 shows that institutional quality (IQ) is positively and significantly correlated with inclusive growth ( $r = 0.5412$ ,  $p < 0.01$ ), the strongest bi-variate association in the matrix and consistent with the large IQ coefficient later reported in Table 10. Climate change (CC) correlates only weakly and marginally with inclusive growth ( $r = 0.1842$ ,  $p < 0.10$ ) at the bi-variate level, underscoring why the full Panel ARDL specification - rather than simple correlations - is needed to isolate the CC effect net of institutions and controls. None of the pairwise correlations among the regressors exceed 0.55, suggesting that multi-collinearity is unlikely to be a serious concern for the long-run estimates that follow.

### Panel Unit Root Test Results

Before estimating the long-run model, the study establishes the stationary properties of each series, including the newly added CC×IQ interaction term. In each case, the null hypothesis is that the variable contains a unit root - that is, that it is non-stationary.

**Table 7: Panel Unit Root Test Results**

| Variable | Level (p-value) | First Difference (p-value) | Order of Integration |
|----------|-----------------|----------------------------|----------------------|
| IG       | 0.6521          | 0.0000***                  | I(1)                 |
| CC       | 0.4123          | 0.0012***                  | I(1)                 |
| IQ       | 0.7890          | 0.0003***                  | I(1)                 |
| CC×IQ    | 0.5214          | 0.0005***                  | I(1)                 |
| RGDP     | 0.5432          | 0.0000***                  | I(1)                 |
| FDI      | 0.3210          | 0.0045***                  | I(1)                 |
| GCF      | 0.4456          | 0.0001***                  | I(1)                 |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, CC×IQ = interaction of Climate Change and Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation. \*\*\* denotes significance at the 1% level, based on Im-Pesaran-Shin (IPS) and Levin-Lin-Chu panel unit root tests.

**Source:** Author's computation using Stata 17, 2026.

Every series is non-stationary in levels but stationary in first differences, confirming that all variables are integrated of order one, I(1). This is the necessary precondition for testing panel co-integration, since the ARDL bounds and Pedroni/Westerlund procedures used below require that no variable be integrated of order two or higher.

### Panel Cointegration Test Results

Following the Pedroni and Westerlund panel co-integration tests, the study next examines whether a long-run relationship exists among the variables. The null hypothesis is that no such co-integration is present.

**Table 8: Panel Cointegration Test Results**

| Test Statistic      | Statistic | Prob. | Result        |
|---------------------|-----------|-------|---------------|
| Panel v-Statistic   | 2.451     | 0.007 | Co-integrated |
| Panel rho-Statistic | -3.120    | 0.001 | Co-integrated |
| Panel PP-Statistic  | -4.892    | 0.000 | Co-integrated |
| Panel ADF-Statistic | -5.103    | 0.000 | Co-integrated |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

All four test statistics reject the null of no co-integration at conventional significance levels, confirming that climate change, institutional quality, and inclusive growth, together with the control variables, share a stable long-run equilibrium relationship. This finding validates the use of the Panel ARDL error-correction framework specified in Section 3.

### Diagnostics: Estimator Choice, Cross-Sectional Dependence, and Slope Homogeneity

**Table 9: Diagnostic Tests**

| Test                                          | Statistic               | Prob.  | Interpretation                                                                                                                                 |
|-----------------------------------------------|-------------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Pesaran CD test                               | 4.821                   | 0.0000 | H <sub>0</sub> rejected; strong evidence of cross-sectional dependence across countries due to unobserved common shocks.                       |
| Slope homogeneity ( $\Delta / \Delta_{adj}$ ) | 6.452 / 7.120           | 0.0000 | H <sub>0</sub> rejected; confirms slope coefficients are heterogeneous across countries in the panel.                                          |
| Hausman test (PMG vs. MG)                     | 2.145                   | 0.3421 | H <sub>0</sub> not rejected; indicates no significant difference between PMG and MG, favoring the more efficient PMG estimator.                |
| Estimator used                                | Pooled Mean Group (PMG) | -      | Preferred based on the Hausman test result, imposing long-run slope homogeneity while allowing short-run dynamics and error variances to vary. |
| Serial correlation (AR test / Wooldridge)     | 1.842                   | 0.1745 | H <sub>0</sub> not rejected; no evidence of second-order serial correlation in the residuals.                                                  |
| Heteroskedasticity (modified Wald)            | 45.620                  | 0.0000 | H <sub>0</sub> rejected; presence of group-wise heteroskedasticity, addressed via robust standard errors.                                      |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

Two key findings from this diagnostic battery underpin the selection of the econometric estimator. First, the Pesaran cross-sectional dependence (CD) test decisively rejects cross-sectional independence a predictable outcome for geographically linked economies subjected to shared environmental shocks and global commodity price fluctuations. Consequently, cross-sectionally robust standard errors are employed across all specifications to prevent spatial dependence from artificially inflating statistical precision. Second, the slope-homogeneity tests verify that short-run adjustment trajectories vary significantly across countries, whereas the Hausman test fails to reject the restriction of long-run coefficient homogeneity between the Pooled Mean Group (PMG) and Mean Group (MG) estimators. Because the PMG estimator imposes long-run slope restrictions exclusively where validated by the data and delivers greater efficiency than the MG estimator when those restrictions hold, it is selected as the primary estimation technique for Table 10.

### Long-Run Estimates and Conditional Marginal Effects.

**Table 10: Panel ARDL Regression Results, Long Run (Dependent Variable: Inclusive Growth, IG).**

| Regressor                                   | Long-Run Coefficient | Std. Error | t-Statistic | Prob. |
|---------------------------------------------|----------------------|------------|-------------|-------|
| Climate Change (CC)                         | -0.425               | 0.082      | -5.18       | 0.000 |
| Institutional Quality (IQ)                  | 0.612                | 0.115      | 5.32        | 0.000 |
| CC × IQ (Interaction)                       | 0.315                | 0.078      | 4.04        | 0.000 |
| Real GDP per capita (RGDP)                  | 0.384                | 0.074      | 5.19        | 0.000 |
| Foreign Direct Investment (FDI)             | 0.128                | 0.041      | 3.12        | 0.002 |
| Gross Capital Formation (GCF)               | 0.156                | 0.052      | 3.00        | 0.003 |
| Error Correction Term (ECT <sub>t-1</sub> ) | -0.342               | 0.065      | -5.26       | 0.000 |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation. Estimator: Pooled Mean Group (PMG) ARDL. Number of observations = 256.

**Source:** Author's computation using Stata 17, 2026.

### Conditional Marginal Effects Analysis ( $\partial IG/\partial CC = \beta_1 + \beta_6 \cdot IQ$ )

To empirically substantiate the paper's core moderation hypothesis that robust governance frameworks mitigate or reverse the adverse socio-economic fallout of environmental stress on inclusive growth the conditional marginal effect of climate change (CC) on inclusive growth (IG) is evaluated across representative percentiles of institutional quality (IQ). Because the estimated interaction coefficient ( $\beta_6$ ) is positive and statistically significant, this marginal effect increases progressively (becoming less negative) as institutional quality improves: specifically, each one-unit enhancement in institutional quality neutralizes 0.315 units of the direct climate penalty. Consequently, the net developmental damage inflicted by environmental stress is not uniform, but depends critically on a given country's relative positioning within the regional institutional quality distribution.

### Low-IQ Environment (10th percentile, IQ = -1.15):

$$\partial IG/\partial CC = -0.425 + 0.315(-1.15) = -0.787 \text{ (} p < 0.01 \text{)}$$

Interpretation: In nations characterized by weak institutional governance, climate shocks impose a severe,



statistically significant drag on inclusive growth reaching nearly double the magnitude of the baseline average effect implied by  $\beta_{61}$  in isolation.

### High-IQ Environment (90th percentile, $IQ = 0.85$ ):

$$\partial IG/\partial CC = -0.425 + 0.315(0.85) = -0.157 \text{ (statistically insignificant)}$$

Interpretation: As institutional quality improves toward the upper decile, the direct negative drag of climate change is substantially dampened, eventually attenuating toward zero and losing statistical significance.

### Johnson - Neyman Threshold Calculation

Setting the marginal effect equal to zero ( $\beta_1 + \beta_6 \cdot IQ = 0$ ) yields the critical threshold at which institutions fully neutralize the climate penalty:

$$IQ^* = -\beta_1/\beta_6 = -(-0.425)/0.315 \approx 1.349$$

This Johnson-Neyman threshold conveys a critical policy implication: a nation's institutional quality must surpass approximately 1.35 standardized units to completely neutralize the negative developmental impacts of climate volatility on inclusive growth. Given that the sample's institutional quality distribution peaks well below this benchmark Table 5 reveals a maximum value of 1.420, attained by only a small fraction of country-years virtually no country in the panel consistently achieves or sustains this threshold. Consequently, while robust governance functions as an essential protective shield against environmental shocks, reaching an institutional tipping point where climate change ceases to impede inclusive growth necessitates deep, continuous, and long-term structural reforms rather than sporadic or isolated policy interventions.

### Short-Run Dynamics

Table 11 displays the short-run parameter estimates derived from the error-correction formulation in Equation (4). In contrast to the long-run co-integrating vectors, these coefficients capture the immediate, contemporaneous adjustments of inclusive growth to shifts in environmental stress, governance metrics, and macroeconomic controls, prior to the system's convergence back to its long-run equilibrium trajectory.

**Table 11: Panel ARDL Regression Results, Short Run (Dependent Variable:  $\Delta IG$ ).**

| Regressor                                | Short-Run Coefficient | Std. Error | t-Statistic | Prob. |
|------------------------------------------|-----------------------|------------|-------------|-------|
| $\Delta$ Climate Change (CC)             | -0.095*               | 0.052      | -1.827      | 0.069 |
| $\Delta$ Institutional Quality (IQ)      | 0.210***              | 0.064      | 3.281       | 0.001 |
| $\Delta$ CC $\times$ IQ (Interaction)    | 0.048**               | 0.022      | 2.182       | 0.031 |
| $\Delta$ Real GDP per capita (RGDP)      | 0.312***              | 0.081      | 3.852       | 0.000 |
| $\Delta$ Foreign Direct Investment (FDI) | 0.084**               | 0.038      | 2.210       | 0.029 |
| $\Delta$ Gross Capital Formation (GCF)   | 0.165***              | 0.045      | 3.667       | 0.000 |
| Constant                                 | 0.041*                | 0.023      | 1.782       | 0.077 |

**Note:** \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels respectively. IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

The short-run interaction coefficient (0.048) shares the same positive sign as its long-run counterpart (0.315), though it is an order of magnitude smaller in magnitude. This empirical pattern aligns with theoretical priors, confirming that institutional buffering functions primarily as a gradual, structural mechanism rather than an immediate shock-absorber capable of neutralizing climate volatility within a single year. In the short run, climate shocks still bite - the immediate effect of CC is negative and marginally significant - but the moderating role of institutions strengthens only as the system converges toward its long-run path, reinforcing the case made in Section 4.5 for treating governance reform as a multi-year undertaking rather than a short-term palliative.

### Robustness Check: Endogeneity

Institutional quality is treated here as potentially endogenous, to allow for possible feedback between governance and development outcomes. Table 12 presents the System-GMM re-estimation of the long-run relationship, in which contemporaneous institutional quality is instrumented with its own first and second lags to mitigate simultaneity bias.

**Table 12: System-GMM / IV Robustness Check**

| Regressor                                         | Coefficient | Std. Error | z / t-Statistic | Prob. |
|---------------------------------------------------|-------------|------------|-----------------|-------|
| Climate Change (CC)                               | -0.142*     | 0.078      | -1.821          | 0.068 |
| Institutional Quality (IQ),<br>instrumented       | 0.315***    | 0.092      | 3.424           | 0.001 |
| CC × IQ (Interaction)                             | 0.089**     | 0.041      | 2.171           | 0.030 |
| Controls (RGDP, FDI,<br>GCF)                      | 0.421***    | 0.105      | 4.009           | 0.000 |
| Hansen/Sargan J-statistic<br>(overidentification) | -           | -          | -               | 0.342 |
| AR(2) test (instrument<br>validity)               | -           | -          | -               | 0.615 |

**Note:** \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels respectively. IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation.

**Source:** Author's computation using Stata 17, 2026.

The sign and statistical significance of both the institutional quality and interaction coefficients remain robust relative to the baseline Pooled Mean Group (PMG) estimates, confirming that the core empirical findings are not driven by reverse causality. Diagnostic evaluations further validate this interpretation: the Hansen J-test fails to reject the null hypothesis of instrument validity, and the AR(2) test detects no evidence of second-order serial correlation in the differences residuals, collectively supporting the reliability of the System-GMM specification. Nevertheless, as highlighted in Section 3.3, while this robustness check alleviates immediate concerns, it cannot entirely eliminate residual endogeneity within a compressed panel of sixteen countries, where establishing reliable instrument strength remains an inherent empirical challenge.

### Alternative Measures and Estimator

Three further checks assess whether the CC×IQ moderation result depends on the specific composite measures or estimator used in the baseline specification, addressing the contrasting findings of Okere and Fasanya [34] and Chamma [35] discussed in Section 2.3.

**Table 13: Robustness to Alternative Measures and Estimator (Dependent Variable: IG)**

| Specification                                                                 | CC×IQ Coefficient | Std. Error | Prob. |
|-------------------------------------------------------------------------------|-------------------|------------|-------|
| Baseline (PMG, full six-indicator IQ, full CC index) - Table 10               | 0.315             | 0.078      | 0.000 |
| Alternative IQ: government effectiveness and regulatory quality only          | 0.276             | 0.091      | 0.003 |
| Alternative CC: temperature anomaly only (excludes CO <sub>2</sub> emissions) | 0.243             | 0.084      | 0.005 |
| Alternative estimator: Cross-Sectionally Augmented ARDL (CS-ARDL)             | 0.288             | 0.096      | 0.003 |

Note: IQ = Institutional Quality, CC = Climate Change. All specifications include the full set of control variables (RGDP, FDI, GCF) and cross-sectionally robust standard errors. CS-ARDL follows Chudik and Pesaran (2015), augmenting the model with cross-sectional averages of the dependent and independent variables to filter out unobserved common factors.

Source: Author's computation using Stata 17, 2026.

Across all three checks, the interaction coefficient remains positive and statistically significant at conventional levels, ranging from 0.243 to 0.288 against a baseline of 0.315. The narrower IQ measure (government effectiveness and regulatory quality only) and the narrower CC measure (temperature anomaly only) both attenuate the coefficient modestly, consistent with the idea that the full six-indicator and two-indicator composites capture somewhat more of the relevant governance and climate-stress variation than either narrower proxy alone. More importantly, the CS-ARDL re-estimation which explicitly filters out the common shocks identified by the Pesaran CD test in Table 9, rather than relying solely on cross-sectionally robust standard errors continues to return a positive and significant interaction term, indicating that the baseline moderation result is not an artifact of modeled cross-sectional dependence. Taken together with the System-GMM/IV check in Table 12, these results suggest the CC×IQ finding is reasonably stable to how institutional quality and climate stress are measured and to the choice of panel estimator, though the attenuation observed under narrower measures also indicates that the magnitude of the moderation effect as opposed to its sign and significance is somewhat sensitive to measurement choice, a caveat noted alongside the other limitations in Section 5.3.

### Economic Interpretation of the Results

The long-run estimates in Table 10 tell a coherent economic story. The coefficient on climate change is negative and significant: holding other factors constant, a one-unit intensification of climate stress - whether through rising temperature anomalies or higher CO<sub>2</sub> emissions - is associated with a 0.425-unit decline in the inclusive-growth index over the long run. This matches the vulnerability-trap argument set out in Section 1: climate shocks fall disproportionately on smallholder agriculture, fisheries, and other climate-sensitive livelihoods that anchor income and food security for the region's poorest households, so damage to these sectors shows up directly in a composite measure of poverty and inequality.

Institutional quality carries a larger, positive, and statistically significant coefficient of 0.612 - the largest in the model. In economic terms, a one-unit improvement in governance quality raises inclusive growth by more than the estimated damage from a one-unit increase in climate stress. This is suggestive of the decoupling mechanism anticipated in the theoretical review; whether well-functioning institutions do more than cushion the shock of climate change - that is, whether they more than offset it - is precisely the question the CC×IQ



interaction coefficient and its associated marginal effects (Section 4.5) are designed to answer directly, rather than inferring moderation from the two main-effect coefficients alone.

The empirical behavior of the control variables aligns closely with conventional macroeconomic theory. Real GDP per capita enters with a positive and statistically significant coefficient, capturing the standard relationship wherein higher aggregate income enhances a nation's fiscal capacity for resource redistribution and social welfare investment. Similarly, both foreign direct investment and gross capital formation are positive and significant albeit modest in magnitude implying that capital inflows and domestic investment foster inclusive growth primarily by expanding the aggregate productive capacity rather than through direct, autonomous distributive mechanisms; thus, their contributions complement institutional enhancement rather than substitute for it.

Crucially, the error correction term is negative and highly significant, confirming system stability and verifying that inclusive growth converges back toward its long-run equilibrium trajectory following exogenous shocks. The estimated coefficient of -0.342 indicates that approximately 34% of any structural disequilibrium such as a severe climate-induced drought or an abrupt institutional setback is corrected within a single year, implying that a permanent one-time shock requires roughly three years to fully dissipate through the system. This reflects a moderate speed of adjustment: rapid enough to validate the economic meaningfulness of the relationships over a statistical artifact, yet sufficiently gradual to underscore why sustained, long-term structural institutional reform rather than short-term emergency responses remains imperative for shielding the region's vulnerable populations from ongoing climate volatility.

## **CONCLUSION, POLICY IMPLICATIONS, AND LIMITATIONS**

### **Conclusion**

Set against the three objectives stated in Section 1, the evidence supports the following conclusions. First, climate change imposes a negative and statistically significant long-run effect on inclusive growth in Sub-Saharan Africa (Table 10), consistent with the vulnerability-trap framing developed in Section 1. Second, institutional quality, measured as a single composite index of governance, is positively and significantly associated with inclusive growth and carries the largest coefficient in the model. Third, the CC×IQ interaction term is positive and significant in both the long-run and short-run specifications (Tables 10 and 11) and survives the System - GMM robustness check (Table 12): governance quality does not merely exert an independent, additive effect on inclusive growth but actively moderates the damage climate stress inflicts on it. The conditional marginal effects in Section 4.5 show that this moderation is substantial - climate damage nearly doubles at low institutional quality relative to the sample average and becomes statistically indistinguishable from zero at high institutional quality - though full neutralization would require institutional quality beyond any level currently observed in the panel.

### **Policy Implications**

The institutional-quality coefficient (0.612) points to a small number of concrete governance priorities for the region. First, because governance quality shows the largest estimated association with inclusive growth of any variable in the model, investment in administrative capacity, judicial independence, and anti-corruption enforcement is likely to yield larger distributional dividends, unit for unit, than climate-specific spending alone. Second, because the CC×IQ interaction confirms moderation, climate-adaptation finance should be explicitly conditioned on, or sequenced alongside, governance reform: the same climate-finance envelope buys less inclusive growth in a low-IQ environment than in a high-IQ one. Third, the error-correction coefficient ( $\lambda = -0.342$ ) implies an adjustment horizon of roughly three years, arguing for governance reforms sustained over a multi-year horizon rather than one-off responses timed to individual climate shocks.

### **Limitations and Directions for Future Research**

Three limitations should be stated plainly. First, this study represents institutional quality and inclusive growth as single composite (PCA - derived) indices rather than as dis-aggregated components; this is a defensible



choice for a sixteen-country panel, but it necessarily obscures which specific governance dimension (for example, corruption control versus regulatory quality) is doing the work, and future research with a larger cross-section could estimate these components separately or in parallel model runs. Second, the sample of sixteen countries limits the power of the cross-sectional-dependence and slope-homogeneity tests reported in Section 4.4, and constrains the credibility of the instrument-based robustness check reported in Section 4.7, where instrument strength is inherently harder to establish in small panels. Third, endogeneity between institutional quality and inclusive growth is only partially addressed by the System - GMM/IV check in Table 12; reverse causality and omitted time-varying shocks (for example, commodity-price cycles or conflict episodes) common to both series cannot be fully ruled out. Future work could extend the sample to the full set of Sub-Saharan African economies, incorporate sub-national or household-level adaptation data, and test the CC×IQ moderation result against alternative institutional-quality proxies to assess its robustness to measurement choice. Expanding the country sample and incorporating more detailed regional and sectoral analyses would also help capture variation in climate vulnerability and institutional effectiveness that a sixteen-country aggregate panel cannot reveal; within this agenda, researchers could examine specific governance components separately - rather than as a single composite index - to identify which institutional factors most effectively reduce climate-related development risks. Finally, incorporating household-level or community-level data would provide greater insight into how climate change influences poverty, inequality, and social resilience at a finer grain than the country-year composite measures used here.

## REFERENCES

1. World Bank. (2020). The Next Generation Africa Climate Business Plan: Ramping Up Development-Centered Climate Action. World Bank Group.
2. UNECA. (2025). Impact of Climate Change on Africa: Urgent Need to Shift the Economic Paradigm. United Nations Economic Commission for Africa.
3. Masron, T. A., & Subramaniam, Y. (2019). Governance, institutions, and climate change resilience in Sub-Saharan Africa. *Frontiers in Environmental Science*, 7, Article 153.
4. Omri, A., Omri, A., Slimani, S., & Belaid, F. (2022). Governance, institutions, and climate change resilience in Sub-Saharan Africa: Assessing the threshold effects. *Frontiers in Environmental Science*, 10, Article 877546.
5. Wandeda, D. O., Masai, W., & Nyandemo, S. M. (2021). Institutional quality and economic growth: Evidence from Sub-Saharan African countries. *African Journal of Economic Review*, 9(4), 106-125.
6. Afolabi, O. E. (2024). Institutional quality and inclusive growth in Sub-Saharan Africa. *African Journal of Economic Review*, 12(2).
7. Kassouri, Y., & Altıntaş, H. (2020). Multilateral environmental agreements, governance, and institutional quality: New evidence from the ecological footprint in SSA. *Journal of Environmental Planning and Management*, 63(12), 2200-2221.
8. IPCC. (2018). Global Warming of 1.5°C: An IPCC Special Report (V. Masson-Delmotte et al., Eds.). World Meteorological Organization.
9. Adodo, A., & Imoudu, M. (2023). People's perceptions of climate change and the effect of a community development project in Nigeria. *International Journal of Social Quality*, 13(1), 1-24. <https://doi.org/10.3167/IJSQ.2023.130103>
10. United Nations. (2024). Causes and Effects of Climate Change. United Nations Climate Action. <https://www.un.org/en/climatechange/science/causes-effects-climate-change>
11. Arwani, A., & Priyadi, U. (2024). The role and contribution of the New Institutional Economics in economic system performance. *Jurnal Simki Economic*, 7(1), 271-288. <https://doi.org/10.29407/jse.v7i1.508>
12. Rodrik, D., Subramanian, A., & Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *Journal of Economic Growth*, 9(2), 131-165.
13. World Bank. (2009). What Is Inclusive Growth? (Ianchovichina, E., & Lundstrom, S., authors).
14. Klasen, S. (2010). Measuring and monitoring inclusive growth: Multiple definitions, open questions, and some constructive proposals (ADB Sustainable Development Working Paper Series No. 12). Asian Development Bank.



15. Commission on Growth and Development. (2008). *The Growth Report: Strategies for Sustained Growth and Inclusive Development*. World Bank.
16. OECD. (2011). *Divided We Stand: Why Inequality Keeps Rising*. OECD Publishing. <https://doi.org/10.1787/9789264119536-en>
17. Anand, R., Mishra, S., & Peiris, S. J. (2013). *Inclusive growth: Measurement and determinants* (IMF Working Paper No. 13/135). International Monetary Fund. <https://doi.org/10.5089/9781484323212.001>
18. OECD. (2019). *Under Pressure: The Squeezed Middle Class*. OECD Publishing. <https://doi.org/10.1787/689afed1-en>
19. Jha, S. (2025). *Climate-Smart Governance: Navigating Institutional Challenges in Africa's Green Transition*. Oxford University Press.
20. Steiner, A., et al. (2020). *Climate change, institutional quality and the challenge of inclusive growth*. World Bank Policy Research Working Paper, No. 9214.
21. Acemoglu, D., & Robinson, J. A. (2012). *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*. Crown Business.
22. Kamah, M., Riti, J. S., & Bin, P. (2021). Inclusive growth and environmental sustainability: The role of institutional quality in Sub-Saharan Africa. *Environmental Science and Pollution Research*, 28(26), 34885-34901. <https://doi.org/10.1007/s11356-021-13125-z>
23. Jinapor, J. A., Abor, J. Y., & Graham, M. (2024). FDI, industrialization and environmental quality in SSA - the role of institutional quality towards environmental sustainability. *Humanities and Social Sciences Communications*, 11, Article 1484. <https://doi.org/10.1057/s41599-024-04000-6>
24. Nginyu, G. G., Fonchamnyo, D. C., Epo, B. N., & Asongu, S. A. (2023). The effects of institutional quality and bio-capacity on inclusive human development in Sub-Saharan Africa. *African Governance and Development Institute Working Paper*, 23/044.
25. Afolabi, O. E., & Oyeleke, O. J. (2024). Institutional quality and inclusive growth in sub-Saharan Africa: Evidence from panel ARDL. *African Finance and Economic Review*, 7(1), 1-20.
26. Abdul-Karim, S., & Alabani, K. (2026). Climate finance and inclusive growth in sub-Saharan Africa: A panel data analysis. *African Journal of Economics and Sustainable Development*, 9(2), 39-67.
27. Oyelami, L. O., et al. (2023). Governance dynamics and climate mitigation strategies in Sub-Saharan Africa: Empirical insights. *Environmental Science & Policy*, 145, 12-28.
28. Acheampong, A. O., & Dzator, J. (2020). The world is getting warmer: How does energy consumption, economic growth, and carbon emissions impact the climate? *Journal of Cleaner Production*, 268, 122176.
29. Bambi, M., et al. (2024). Robust institutions and climate resilience: Governance as a mediator for sustainable development in Africa. *Development Policy Review*, 42(3), e12745.
30. [30] Alkali, A. S., et al. (2020). Climate change, conflict, and institutional fragility in the Lake Chad Basin: A regional perspective. *Journal of African Economies*, 29(4), 312-335.
31. Olabanji, A. K., & Chitakira, M. (2025). Governance and climate adaptation in Africa: A systematic review. *Journal of Environmental Management*, 370, Article 121456.
32. Subramaniam, Y., Masron, T. A., & Azman, N. H. (2022). Governance and climate change: New evidence from African economies. *Frontiers in Environmental Science*, 10, Article 894321.
33. Mesagan, E. P., & Eregha, P. B. (2019). Institutional quality and inclusive growth in Sub-Saharan Africa. *African Journal of Economic Review*, 7(2), 112-130.
34. Okere, K. I., & Fasanya, I. O. (2024). Technological progress in achieving environmental sustainability in Central and Southern Africa: The role of fossil fuels and institutional quality. *Energy Sources, Part B: Economics, Planning, and Policy*, 19(1). <https://doi.org/10.1080/15567249.2024.2361746>
35. Chamma, D. D. (2025). Corruption, political instability, climate change and economic growth in Sub-Saharan African countries. *Cogent Economics & Finance*, 13(1), Article 2570791. <https://doi.org/10.1080/23322039.2025.2570791>



## APPENDIX A: PANEL COMPOSITION AND BALANCE

**Table A1: Countries and Years Covered**

| S/N | Country       | Years Covered | Panel Balance Note                                           |
|-----|---------------|---------------|--------------------------------------------------------------|
| 1   | Nigeria       | 2010-2025     | Balanced panel; all 16 annual observations present (T = 16). |
| 2   | Ghana         | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 3   | Kenya         | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 4   | South Africa  | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 5   | Ethiopia      | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 6   | Rwanda        | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 7   | Tanzania      | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 8   | Uganda        | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 9   | Senegal       | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 10  | Côte d'Ivoire | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 11  | Cameroon      | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 12  | Mauritius     | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 13  | Botswana      | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 14  | Zambia        | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 15  | Mozambique    | 2010-2025     | Balanced panel; complete data coverage across all years.     |
| 16  | Angola        | 2010-2025     | Balanced panel; complete data coverage across all years.     |

**Note:** IG = Inclusive Growth, CC = Climate Change, IQ = Institutional Quality, RGDP = Real GDP per capital, FDI = Foreign Direct Investment, GCF = Gross Capital Formation. The datasets forms a strictly balanced panel comprising sixteen major Sub-Saharan African economies over the 2010-2025 study period, yielding a total of 256 cross-sectional time-series observations.

**Source:** Author's compilation based on World Bank WDI, PovcalNet/WID, and Climate Change Index databases, 2026.

**Table A2: Institutional Quality by Country and Sub-Region, Average 2010-2025**

| S/N | Country      | Sub-Region      | Average IQ (2010–2025) |
|-----|--------------|-----------------|------------------------|
| 1   | Nigeria      | West Africa     | -0.41                  |
| 2   | Ghana        | West Africa     | 0.18                   |
| 3   | Kenya        | East Africa     | -0.05                  |
| 4   | South Africa | Southern Africa | 0.34                   |
| 5   | Ethiopia     | Horn of Africa  | -0.62                  |



|    |               |                 |       |
|----|---------------|-----------------|-------|
| 6  | Rwanda        | East Africa     | 0.71  |
| 7  | Tanzania      | East Africa     | -0.12 |
| 8  | Uganda        | East Africa     | -0.38 |
| 9  | Senegal       | West Africa     | 0.29  |
| 10 | Côte d'Ivoire | West Africa     | -0.09 |
| 11 | Cameroon      | Central Africa  | -0.58 |
| 12 | Mauritius     | Southern Africa | 1.02  |
| 13 | Botswana      | Southern Africa | 0.88  |
| 14 | Zambia        | Southern Africa | -0.21 |
| 15 | Mozambique    | Southern Africa | -0.66 |
| 16 | Angola        | Central Africa  | -0.71 |

Note: IQ = Institutional Quality (PCA composite of six World Governance Indicators, standardized; sample mean = -0.215, SD = 0.673). Sub-regional classification follows the United Nations geoscheme for Africa. The sample spans low- (e.g., Mozambique, Angola, Ethiopia), middle- (e.g., Nigeria, Kenya, Zambia), and high-institutional-quality contexts (e.g., Mauritius, Botswana, Rwanda), supporting the diversity claim made in Section 3.1.

Source: Author's computation from World Bank Worldwide Governance Indicators, 2010-2025 averages.