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Global Climate Commitments, Regulatory Capacity and Carbon Emissions in Sub-Saharan Africa

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Abstract

Despite the proliferation of international climate pledges and national contributions, global carbon emissions continue to rise, undermining efforts to stabilise temperatures at 1.5°C. Such a trend raises serious questions about the effectiveness of the current climate governance framework. Such enduring gaps pose a serious threat to the ability of international climate commitments to deliver real environmental benefits, particularly in countries with weak domestic institutional capacities. This paper analyses the relationship between global climate commitments, regulatory capacity and carbon emissions in Sub-Saharan Africa (SSA) with a focus on the conditional role of institutional quality on global climate governance. This study employs balanced panel data from SSA countries for the period 2009-2024 and utilises the panel random-effects model with interaction and robustness analyses to explore the moderating role of regulatory capacity in the link between global climate commitments and carbon emissions. Results show that increased commitments to global climate change are strongly associated with reductions of carbon emissions, but their effectiveness is highly dependent on the strength of domestic regulatory institutions. The interaction estimates show that the effect of international climate commitments in reducing emissions is intensified when there is a higher level of regulatory capacity, underscoring institutional effectiveness as an important transmission mechanism that links global climate governance and national environmental outcomes. This research contributes to the rapidly expanding literature on climate governance studies from the perspective of new institutional economics, highlighting the importance of governance-dependent policy effectiveness in achieving sustainable decarbonisation outcomes in developing regions.

Keywords: Global climate commitment; Regulatory capacity; Carbon emissions; Climate governance; Institutional effectiveness.

1.0 Overview

To date, the global climate governance structure is approaching a decisive decade; Given the Paris Agreement, countries of the world are bound by increasingly ambitious decarbonization commitments, yet the demonstrable emissions reductions of these agreements into environmental outcomes remains heterogeneous (Tutar, et al., 2026; Halkos & Aslanidis, 2024; IEA, 2023; Ven, et al., 2023). In Sub-Saharan Africa (SSA), where the developmental necessity is structurally energy-dependent, a critical tension arises, leading to such questions as: can international climate commitments broadly reduce emissions in situations where regulatory institutions are still consolidating? This study addresses such "institutional-policy gap" which is one of the bottlenecks that threatens to stall the SSA's region's transition to a low-carbon economy.

The marginal contributions of SSA to historical global emissions, shows a distinct structural frontier for the worldwide net zero transition. This is contrary to the developed countries that

must decarbonize existing infrastructure unlike SSA that are just building up most of its urban centers and industrial base. This creates an analytically unusual time bound advantage or window for low-carbon leapfrogging enabling nations to avoid fossil-fuel lock-in and moving toward such a distributed renewable energy system (Singh, et al., 2026; IPCC, 2022; Moreno, et al., 2024; Fuhrman, J. et al., 2024).. However, the extent of this potential is constrained by an effective policy implementation gap; yet, while the policy enactment for commitments to renewable energy and international climate agreements is increasing, domestic regulatory (REG) needed to monitor emissions as well as enforcement of green standards in most cases has not kept pace with policy enactment

Recent empirical literatures are far from unanimous. For example, studies like Hoang, 2023; Frank, 2023; and Farooq, et al., 2022 stated that climate commitments and governance reforms significantly contribute to emission reductions in different regions. On other hand, some studies show scanty or statistically insignificant impacts, especially in nations characterised by weak institutional and regulatory structures. While another strand of evidence denotes that the effectiveness of climate commitments is conditional on governance quality and implementation capacity. Hence, it may then be deduced that no clear consensus has been reached regarding whether climate commitments alone are adequately enough to reduce emissions, especially in the context of Sub-Saharan African.

Likewise, most of the previous studies also concentrated on environmental Kuznets curves (EKC) through income channels, yet they did not show the reason why nations that have similar GDP levels depict high different emissions pathways. This study argues that the overlooked explanatory factor of the under-theorized mechanism is basically the conditional threshold of governance. This study put forward to the existing climate policy debate by positioning regulatory quality not as a conventional control variable but as structural moderator that indicates whether Global Climate Commitments (GCL) effectively translate into quantifiable Carbon Emission (CEM) reductions

By incorporating a detailed framework that takes into consideration Industrial Value Added (IVA), Urbanization (URB), and Energy Consumption (ENE), this research presents a forward-looking lens on how developing countries can align structural industrial transformation with global climate commitments (SDGs 7, 13, and 16). This analysis provides a strategic roadmap or an evidence based framework, implying that success of Africa's structural transition hinges less on the volume of international agreements and much more on the institutional development of the governments mandated with their implementation.

1.1 Introduction

The central paradox of the era of net-zero commitments relies solely not on the absence of climate commitments but also on the persistent escalation of global carbon emissions despite an unparalleled expansion of agreements, nationally determined contributions, and multilateral decarbonisation pledges (Akpensuen & Rivero, 2025; Bian, et al ., 2024; Issa, 2025; Joo, Paavola & Van, 2023). Even though, the well-known Paris-aligned decarbonization framework has withness a significant multilateral consolidation across both advanced and emerging nations, global carbon dioxide (CO_2) emission continues to sway from pathways consistent with restricting global temperature increase to 1.5°C above pre-industrial levels. Such divergence reveals the continual lapses in the institutional enforcement and implementation strength and capacity of global climate governance architecture (Stuart- smith, et al., 2025; König-Sykorova,

2026; Issa, 2025; Akpensuen, and Rivero, 2025; Bjørn, et al., 2021; Immink, et al., 2022; Joo, et al., 2023). This contradiction is systemically essential for structurally transforming emerging countries, where fossil-dependent growth trajectories intersect with increasingly stringent decarbonization requirements, reinforcing the risk of carbon lock-in and stranded developmental trajectories (UNFCC, 2022; Frank, 2023; Joo, et al., 2023; LSEG, 2023; Hoang, 2023). Converging empirical studies indicate that in the absence of credible enforcement mechanisms as well as institutional discipline, climate commitments risk institutional decoupling or reduced to aspiration diplomacy rather than material emissions reduction (Bulkeley, and Newell, 2023; Immink, et al., 2022; Vieira, et al., 2022; Owojori, &Anwana, 2025; Afuye, & Tolios, 2026). Strengthening such institutional enforcement architecture is becoming critical and urgent, as delayed correction steps or sustained policy inertia not only escalate climatic tipping thresholds but also erodes the long-term legitimacy and operational capacity of the global decarbonization regime (Elliott, et al., 2023; OyenugA, et al., 2025; Doan, et al., 2024; Bernstein S,& Hoffmann M 2018; Evro, et al., 2024).

The structural non-alignment between climate commitments and outcomes in Sub-Saharan Africa indicates structural and institutional weaknesses in regulatory capacity that restricts the credible implementation of global climate commitments (GCL) into measurable mitigations in carbon emissions (CEM). Although, renewable energy consumption has increased greatly across many economies in the region, yet operational improvements in regulatory quality (REG) have not well developed at a commensurate pace, creating uneven enforcement structures that weaken compliance and dilute policy credibility (Dona, 2025; Javed, et al., 2024; Li,et al 2022; Alola & Adebayo, 2023; Aminu, et al., 2023; Ayanlade, et al., 2023). In many SSA countries, increasing GDP per capita (GDP) remains closely associated with carbon-intensive industrial value added (IVA) and fossil-dependent energy consumption (ENE), intensifying the structural coupling between economic development and emissions growth (Jaumotte, et al., 2024; Dai, et al., 2025; Ahakwaet, al., 2023; Ali,et al., 2022; Amin, et al., 2023). Most economies that exhibit high rate of industrial expansion, concentrated use of energy consistently exceeding institutional oversight capacity which is usually required to enforce environmental standards and mostly applicable in highly improved urbanization (URB) that also strengthens infrastructure requirements (Pata, et al., 2023; Zhou&Lin, 2025; Amowine, et al., 2023). Likewise, the Tradeo penness (TRD), which is growth enhancing in most economy may augment carbon leakage impacts especially in the economy where regulatory enforcement is not adequate, thereby attenuating the environmental effectiveness of domestic climate pledges (Elliott et al., 2023; Bian, et al., 2024; Cheng, et al 2022). Previous empirical studies shows that climate commitments give rise to heterogeneous emissions outcomes across institutional contexts, denoting that regulatory quality roles as a conditioning framework shaping the magnitude and direction of decarbonization effects rather than as a mere control variable (Joo et al., 2023; Churchill, et al., 2018; Farooq, et al 2022; Li, et al., 2024). Consequently, the persistence of emissions growth in SSA indicates the interaction between climate ambition and institutional capacity, indicating that commitments will yield meaningful reduction only where governance structures reflect sufficient regulatory depth and enforcement credibility.

Existing efforts among the scholars to redress the persistence increasing carbon emissions in this region have largely been hinged in the Environmental Kuznets Curve (EKC) frameworks, which states that environmental degradation initially increases with income but reduces after a structural transformation threshold has been reached (Churchill, et al., 2018; Ozcan, et al., 2018;

Nathaniel, et al., 2020; Nathaniel & Khan, 2020). While these paradigms has developed an extensive empirical testing across sub–Saharan African countries, its explanatory power remains scanty, especially in accounting for persistent cross-country heterogeneity in emissions trajectories among nations with comparable gross domestic product per capita levels (Sarkodie, 2022; Murshed, 2022; Jahanger et al., 2022). A first vacuum that this study pinpoints relates to the insufficient research on the institutional conditionalities underpinning decarbonization. However, to the best of our knowledge, few studies explicitly and comprehensively investigate whether the effectiveness of global climate commitments (GCL) depends or relies on domestic regulatory quality (REG) within the SSA context (Aykut, et al., 2022; Joo et al., 2023; Vieira, et al., 2022).

Secondly, there persists inadequate of knowledge concerning the mechanism through which renewable energy increase translates into emissions reduction under changing governance conditions. Although, most of the previous research documents the roles of energy consumption (ENE), urbanization (URB), industrial value added (IVA), and trade openness (TRD) in shaping carbon emissions (Bexell, et al., 2022; Cheng et al., 2022; Bian, et al., 2024; Dai, et al., 2025), it is not yet clear whether climate agreements develop uniform and consistent reduction and or mitigation effects across diverse weak and strong institutional environments. Such omission and sometimes partial absence (in some regions) of interaction-based modelling obscures how regulatory maturity conditions policy transmission channels.

Thirdly, there exist limitations in previous empirical approaches which continually contribute to inconclusive findings. Many studies on similar topics adopt additive specifications in which regulatory indicators are treated as peripheral control variables rather than structural moderators (Unger, 2023; Dogan et al., 2022; Javed, et al., 2024). Such models in those circumstances assume static policy effectiveness which fails to explain why renewable energy growth frequently coexists with increasing carbon intensity in resource-dependent African nations (Acheampong et al., 2024; Murshed, 2024). Furthermore, the panel estimations often overlook institutional heterogeneity and threshold effects, which constrains the interpretation of climate policy outcomes, making them appear uniform rather than context-contingent. (Zürn, 2018; Bexell, et al., 2022, Zelli, et al., 2023).

This last point relates to the practical implementation issues that reveal a continuous policy execution gap. Leaders and heads of governments in this region truly adopted ambitious global climate commitments that strictly aligned with international frameworks; however, some factors such as enforcement capacity, regulatory credibility, and monitoring mechanisms often lag behind formal agreements (Alola & Adebayo, 2023; Dona, 2025; Oyenuga et al., 2025). This misalignment leads to a scenario in which climate ambition expands without proportional institutional strengthening, weakening the material impact of decarbonization strategies. Consequently, reliance on growth-centered or energy-transition narratives without embedding regulatory thresholds risks perpetuating carbon lock-in dynamics (Zhou &Lin, 2025; Jaumotte et al., 2024). Given those reasons, It can otherwise be stated that scholars has not completely and sufficiently theorized nor empirically tested the moderating role of regulatory quality in conditioning the emissions impact of global climate commitments in the economies of sub Saharan Africa.

Rooted in the pointed-out institutional and empirical gaps, this research investigates the relationship among Global Climate Commitments (GCL), Regulatory Quality (REG), and Carbon Emissions (CEM) in Sub-Saharan Africa over the period 2010–2025. The aim of this research is to investigate whether the emissions-reducing effect of climate commitments is contingent upon the maturity of domestic regulatory institutions. Most of the recent evidence indicates that renewable energy adoption and formal climate agreements do not automatically translate into decarbonization in weak enforcement countries (Dona, 2025; Abaidoo & Agyapong, 2025; Bexell et al., 2022; Zhou, &Lin, 2025; König-Sykorova, 2026).

This study enhances the literature in three principal ways. First, it moves away from the conventional additive Environmental Kuznets Curve (EKC) specifications by bringing in or introducing an interaction-based framework (GCL×REG), thereby comprehensively and explicitly modeling regulatory quality as a conditioning mechanism rather than a peripheral control variable (Churchill, et al., 2018; Ozcan, et al., 2018; Abaidoo & Agyapong, 2025; Jahanger et al., 2023; Zhao et al., 2024). This restructuring and repositioning provide room for strict identification of governance-contingent effects of climate policy. Second, by integrating such structural keys including urbanization (URB), industrial value added (IVA), and energy consumption (ENE) especially within a scale-adjusted log–log specification, the research offers a decomposed assessment of the emissions structure in SSA, which then address or correct the static policy assumption prevalent in most previous studies (Zürn,; Wang & Zhang, 2024). Third, the empirical strategy takes into consideration or account for country-specific heterogeneity and cross-sectional dependence, strengthening the robustness of inference in a region characterized by institutional and macroeconomic volatility (Dogan et al., 2024; Bäckstrand, et al., 2021). Such will help in shifting analytical focus from income-based turning points to governance-based thresholds, this makes the study adds a more institutionally grounded explanation of climate policy effectiveness in developing economies.

Concerning the practical roles or significance of this study, this significantly lies in its capacity to move empirical evidence into governance-oriented climate strategy. Through pointing out or revealing whether regulatory quality conditions the effectiveness of climate commitments, the results provide policymakers with a measurable institutional standard and benchmark for improving enforcement capacity, regulatory coherence, and monitoring systems. This allows respective concerned governments to prioritize institutional strengthening alongside renewable energy expansion, ensuring that climate pledges develop verifiable emissions mitigations rather than mere symbolic compliance. The findings hence support more efficient allocation of fiscal and administrative resources toward institutional reforms that increase decarbonization outcomes.

The remainder of the paper proceeds as follows. Section two reviews the relevant literature and theoretical foundations. Section three outlines the data, variable construction, and econometric methodology. Section 4 presents the empirical findings and robustness analyses while section five concludes with policy implications and avenues for future research.

2.0 Conceptual Framework

In order to have the general perspective of how global climate commitment and the regulatory capacity of nations translate into emission outcomes; Figure 1 shows the conceptual framework

of the study. The framework shows the institutional mechanisms as presented in New Institutional Economics and policy implementation theory, through which global climate commitments only reduce emissions effectively when countries have strong regulatory capacity and this also depends on other structural factors like energy use and industrialization**.**
More so, it includes the structural determinants of emission such as: energy consumption, urbanization, industrial value added, and trade openness that are always given preference in environmental economics. In doing that, governance-contingent natures of climate policy effectiveness in Sub-Saharan Africa are not left out. As a result, the environmental effect of climate commitments is expected to vary across countries depending on the quality of regulatory governance. The framework takes into consideration the interaction effect between global climate commitments and regulatory capacity, while also controlling for structural drivers of emissions including energy consumption, urbanization, industrial activity, and trade openness.

This research contributes extensively to the progress of achieving and advancement of United Nations Sustainable Development Goal 13 (Climate Action) by investigating the institutional conditions under which global climate commitments translate into effective emission reduction outcomes in developing economies especially in SSA. The analysis also relates to SDG 16 (Peace, Justice and Strong Institutions) by focusing on the roles of regulatory capacity and governance quality in shaping climate policy enforcements and implementations, to SDG 7 (Affordable and Clean Energy) through the consideration of energy consumption dynamics in the decarbonization process.

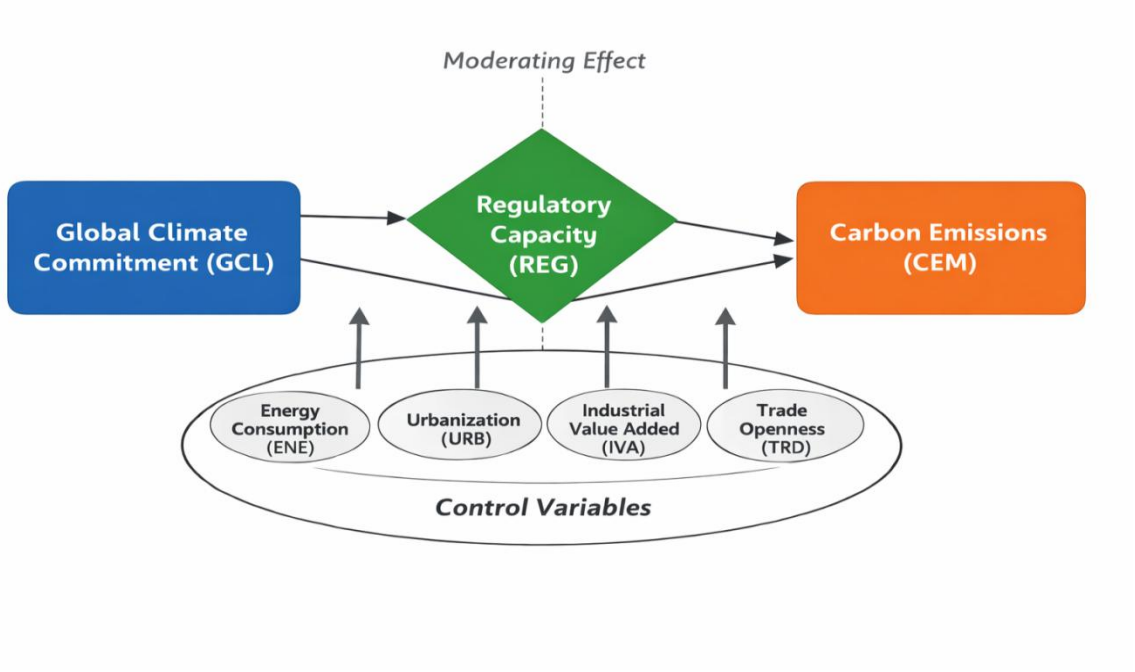


Figure 1:Governance-Contingent Climate Effectiveness Framework

2.1 Theoretical Framework

2.1.1 Institutional Foundations of Climate Governance

This research is hinged in the New Institutional Economics (NIE), as provided in the foundational insights of Douglass North (1990) and Oliver Williamson (2000). NIE reiterated the significance of institutions in structuring incentives, reducing uncertainty, and shaping economic and policy outcomes. Institutions here according to North (1990) are known as humanly devised limitations that structure human interaction, taking into consideration both formal rules (laws, regulations, property rights) and informal norms that govern behavior. Given this perspective, environmental and climate outcomes in most cases are not being regulated and determined mainly by economic growth or technological change but by the institutional environment that regulate and governs the policy enforcement and compliance. The institutional framework as provided by North (1990) shows how governance structures determine the credibility of policy commitments and the ability of states to enforce regulatory rules over time.
Similarly, Williamson in work developed a related logic of transaction costs and governance structures. This logic emphasis that in presence of imperfect information and opportunistic behavior, institutions appears as governance mechanisms developed to reduce the transaction costs related to enforcement and monitoring. As a result, the effectiveness of environmental rules and policies depends on the institutional set up that facilitate monitoring, enforcement, and compliance. Specifically, concerning climate governance, global climate commitments (GCL) represent a formal policy agreement targeted towards reducing carbon emissions. However, the NIE perspective indicates that such commitments cannot develop uniform outcomes across nations as institutional quality changes substantially. Likewise, regulatory capacity determines whether policy commitments translate into enforceable internal policies or remain largely symbolic. It is pointed out that in weak institutional environments, enforcement costs are usually high and compliance incentives are relatively low, leading to policy slippage and inconsistent enforcement.

The NIE institutional paradigm is most relevant for SSA context, the state where regulatory environments indicate a significant heterogeneity. Such differences in administrative coordination, legal enforcement mechanisms, and bureaucratic effectiveness produce varying levels of institutional credibility across or throughout the nations. Consequently, the environmental effect of global climate commitments is very likely to be conditional on domestic regulatory capacity of specific nation rather than uniform across the region.

Importantly, approaching study from look of climate governance effectiveness, global climate commitments alone would and do not automatically lead reductions in carbon emissions. Their effectiveness conditionally depends more on the institutional capacity of respective nations to translate formal environmental obligations or duties to implementation of domestic policies through: compliance enforcement monitoring, administrative implementation and regulatory coordination. Inherent in NIE theoretical framework, regulatory capacity is said to functions not merely as an ordinary supporting institutional characteristic, but also as one of the governance transmission mechanisms through which climate commitments translates and change operationalized into measurable environmental outcomes. This simply means that nations with stronger institutional and regulatory mechanisms are in better position to achieve effective climate governance since they inherently possess the likely administrative capability needed to

enforce environmental regulations, reduce and or less policy slippages, and guarantee compliance within economic actors.

Also, climate governance effectiveness can sometimes depend on broader structural economic conditions like: urbanization pressures, industrialization intensity, energy consumption patterns and trade openness. Most of such structural factors may facilitate, encourage, or restrict and constrain the enforcement of climate policies, especially in emerging nations where economic growth goals may compete with environmental sustainability objectives. As a result, the relationship between climate commitments and carbon emissions in Sub-Saharan Africa might be institutionally conditioned and structurally heterogeneous rather than uniform across nations

Notably, positive interaction between Global Climate Commitments and Regulatory Capacity is likely to show the existence of transitional institutional changes or dynamics in emerging nations. Though, it is noted that stronger regulatory capacity strengthens policy coordination, monitoring, and implementation, institutional strengthening in Sub-Saharan Africa all of which are likely to accommodate accelerated industrialization, expanding energy utilization, and enhanced formal economic activities that mount upward pressure on carbon emissions in the short-to-medium term. This simply means that, effectiveness of climate commitments is not likely to produce or yield instant linear reductions in emissions, but rather produce a gradual institutional adjustment process through which long-run environmental governance effectiveness eventually appears and develops.

2.1.2 Institutional Corruption and Governance Constraints

Another clear perspective of the institutional dimension in shaping climate policy effectiveness in the same region of SSA concerns the prevalence of governance distortions and corruption. Institutional corruption can clearly distort regulatory enforcement, restraining monitoring systems, and hinder policy implementation processes. According to Patibandla (2024), institutional corruption develops when formal rules exist but are systematically subverted by authorities who manipulate institutional processes for private gains. Such corruption not only distort the effectiveness but also weakens the credibility of regulatory systems and erodes public confidence in governance structures.

In this context, it is very possible for corruption to manifest through weak enforcement of environmental regulations, preferential treatment for polluting industries, and or misallocation of climate finance resources mostly in environmental governance. These distortions increase the transaction costs associated with policy enforcement and reduce the likelihood that climate commitments translate into actual emission reductions. As a result, it is possible that institutional corruption will represents a critical mechanism through which regulatory capacity affects climate policy outcomes.

More so, in the context of NIE perspective, corruption can be interpreted or described as a form of institutional failure, where implementation as well as enforcement mechanisms fails to align incentives with policy objectives. Whenever regulatory institutions are captured or compromised, the enforcement credibility necessary for effective climate governance is in most circumstances weakened. Consequently, institutional quality, including the ability to curb or reduce corruption plays a crucial and fundamental role in determining whether climate commitments produce meaningful environmental outcomes.

2.1.3 Policy Implementation and Institutional Transmission Mechanisms

The NIE context seems not fully specify how policy commitments translate into measurable outcomes especially in the real interpretation and meaning; although, the theory clearly explain why institutions matter for policy effectiveness. To address this transmission mechanism, this study incorporates insights from Top-Down Policy Implementation Theory, especially the work of Jeffrey Pressman and Aaron Wildavsky.

Pressman and Wildavsky (1973) emphasis the concept of policy implementation as a hierarchical process through which policy directives pronounced at higher levels of government are translated into operational and implementation actions by administrative agencies. Implementation takes into consideration of multiple decision points and institutional actors, each of which can introduce delays, distortions, or coordination failures.

Such framework thereby reiterated that successful policy outcomes depend not only on policy design but also on the capacity of bureaucratic institutions to coordinate, monitor, and enforce policy goals. Policies formulated at the so called "top" of the political system must pass through rigorous complex administrative chains before producing tangible outcomes. Each stage in the implementation process introduces potential points of failure, particularly in contexts where institutional capacity is limited.

Applied to climate governance, global climate commitments represent high-level policy directives that require domestic institutional translation. Implementation requires administrative capacity to design regulatory instruments, monitor emissions, enforce compliance, and coordinate policy actions across sectors. Where regulatory institutions are weak, the policy transmission chain becomes fragmented, reducing the effectiveness of climate commitments.

contrarily, countries with stronger regulatory institutions are better positioned to translate international commitments into enforceable domestic regulations. Administrative coordination, regulatory monitoring, and compliance enforcement strengthen the policy transmission mechanism and enhance the likelihood of achieving emission reductions.

2.1.4 Governance-Contingent Climate Effectiveness

It is essential to clarify that while Environmental Kuznets Curve (EKC) hypothesis still represents one of the influential and core perspectives in environmental economics, recent environmental governance studies continually suggests that carbon-reduction outcomes are in most cases shaped not only by income changes but also by institutional and regulatory effectiveness (Acheampong et al., 2022; Rafaty et al., 2024; Dogan & Inglesi-Lotz, 2023). In many emerging nations, especially in Sub-Saharan Africa (SSA), continual environmental degradation and weak climate-policy outcomes continue to coexist with economic growth, which shows that income enhancement alone may not sufficiently and totally guarantee environmental sustainability. As a result, contemporary scholars are now shifting attention toward institutional governance frameworks that reiterate regulatory quality, implement capacity, policy coordination, as well as enforcement effectiveness in describing climate-transition outcomes. Hence, this study adopts an institutional governance perspective to investigate how regulatory and institutional mechanisms condition the effectiveness of global climate commitment towards reducing carbon emissions in African nations.

Merging NIE with policy enforcement theory yields a governance-contingent framework of climate policy effectiveness. NIE describes how institutional environments shape and motivating incentives and enforcement credibility, while policy implementation theory pinpoints how policy commitments are translated into operational outcomes through administrative processes and systems.

Combining these two theoretical ideas indicate that the environmental effect of global climate commitments depends solely on domestic institutional capacity. Specifically, regulatory quality influences the effectiveness of climate commitments by shaping the credibility, monitoring, and enforcement mechanisms necessary for policy implementation.

This apparently results to the logic that leads to the central theoretical proposition of this study: the effect of global climate commitments on carbon emissions is conditional upon regulatory capacity. Instead of just assuming similar set of or a uniform policy effect across the economies, the framework proposes that institutional environments mediate the relationship between climate commitments and emission outcomes.

To capture this conditional relationship, the study employs an interaction-based empirical specification, where the effect of global climate commitments (GCL) on carbon emissions (CEM) depends on the level of regulatory capacity (REG) in the institution under consideration. The addition of such interaction term (GCL×REG) shows the theoretical expectation that institutional quality modifies the effectiveness of climate policies.

The inclusion of such approach distinctively moves away from the additive models commonly used in environmental economics, where governance indicators are treated as control variables rather than structural moderators. Since institutional theory is of the opinion that policy effectiveness is inherently context-dependent, this simply means that additive estimations implicitly assume that climate commitments have similar impacts across institutional contexts. In such situation, modeling regulatory capacity as an interaction term a-theoretically offers well-grounded approach for capturing institutional heterogeneity in climate policy outcomes.

2.1.5 Empirical Specification and STIRPAT Foundation

This study employed empirical specification that is theoretically rooted in the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework, that strictly extends the conventional IPAT identity into an econometrically estimable environmental model. The framework of STIRPAT describes the environmental pressure as a function of structural, economic, technological, and demographic factors impacting ecological outcomes. Contrary to the deterministic IPAT identity, STIRPAT allows stochastic estimation and flexible incorporation of more institutional and policy-related variables.

In this research, carbon emissions denote environmental impact component, while economic growth, population dynamics, energy-related structural conditions, and governance variables take into consideration the broader drivers of environmental dynamics. This framework is mostly appropriate as it permits institutional quality and regulatory capacity to be included as conditioning variables affecting the effectiveness of climate governance mechanisms.

On a similar note, such baseline empirical model permits or extends the general STIRPAT specification by merging global climate commitments and regulatory capacity into the environmental effect function. Such addition and extension shows the theoretical argument that

climate policy effectiveness is not recognized solely by both economic and demographic pressures, but also determined by the institutional capability of nations to enforce environmental commitments under dynamic structural conditions.

2.1.6 Conceptual Implications for Empirical Analysis

Given the core framework on the integration of NIE and policy implementation theory, the conceptual framework of this study posits that global climate commitments influence carbon emissions both directly and conditionally through regulatory capacity. Regulatory institutions affect emission outcomes not only through their independent impact on environmental governance but also by moderating the effectiveness of climate commitments. As it is, the empirical model examines three interrelated relationships: the direct effect of global climate commitments on carbon emissions, the direct influence of regulatory capacity on environmental performance, and the interaction effect capturing governance-contingent climate effectiveness.

This study models the empirical relationships simultaneously; the study also contributes to the literature by providing a theoretically grounded explanation for heterogeneous climate policy outcomes across institutional contexts. Through submission of such contribution, this study advances an institutional perspective on climate governance that highlights the critical role of regulatory capacity in translating global commitments into meaningful environmental change.

3.0 Methodology

3.1 Data and Methods

This study examines the relationship between global climate commitment, regulatory capacity, and carbon emissions in Sub-Saharan Africa from 2009 to 2024. The choice of the time frame has been selected not only due to availability of data and consistency across the region in World Development indicators (WDI) and World Governance Indicator (WGI) which gives room for balanced panel and robust analysis, but the period also increases policy importance of the study by including latest emission trends and regulatory developments, thereby offering an insights for the ongoing policy debates relating to climate in SSA. The period also takes cognizance of post global financial crisis era in which climate governance and environmental regulations (especially after the 2009 Copenhagen Accord COP15), becomes prominence especially in the international policy orientations. This represents an important starting point for investigating for responses in this region.

The study covers twenty selected Sub-Saharan African countries. The economies include: Côte d'Ivoire, Cameroon, Ghana, Ethiopia, Tanzania, Uganda, Rwanda, Senegal, Nigeria, South Africa, Kenya, Ethiopia, Togo, Burkina Faso, Zambia, Zimbabwe, Mozambique, Namibia, Malawi, and Benin.The choice of the countries is also based on data availability as well as many factors such as regional imbalances; the variation that exists in emission intensity; exposures to climate vulnerability and combinations of resource rich agrarian countries. Also, this research utilises panel pooled OLS, fixed effect and random effects models for the estimations; While Pooled OLS serves as a baseline, Fixed and random effects models takes into consideration an unobserved heterogeneity across cross-sectional units. However, Hausman specification test has used in the study to select the preferred estimator.

The core variables employed in the research include: carbon Emission; Global climate commitments; and regulatory capacity. While control variables employed are obtained from

WDI include**:** GDP per capita, energy consumption, urbanization, trade openness and industrial value added. All of them have been obtained strictly to ensure not only for cross country comparability but also for replicability and consistency overtime.

Given the extended STIRPAT framework and the governance-contingent institutional perspective employed in this research, the baseline empirical model is specified as follows:

$$CEM_{it} = \alpha_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + \beta_3 X_{it} + \Upsilon_t + \varepsilon_{it} \quad (1)$$

Where: CEM_{it} is defined as the Carbon emissions indicator in country *i* at time *t; GCI* refers to Global climate commitment; *REG* is the Regulatory capacity and X simply refers to the vector of the control variables; α is the Country-specific fixed effects capturing time-invariant heterogeneity; γt is also the time fixed effects capturing common global shocks while *e* is the error term.

This model (1) represents the baseline specification which estimates the mean effect of global climate commitment as well as regulatory capacity on emission while also controlling for other factors like structural, economic and energy.

In order to reduce the potential omitted-variables bias coming up from unobserved heterogeneity across countries and over time, the empirical estimations also include country-specific as well as time-specific fixed effects. The addition of country fixed effects controls for time-invariant structural characteristics such as socio-political conditions, geography, and institutional legacy that may systematically affect environmental outcomes throughout SSA countries. Likewise, time fixed effects take into consideration for common global shocks or changes and temporal dynamics, as well as international climate-policy transitions, global energy-price fluctuations, technological dynamics and macroeconomic disruptions that also simultaneously affect all the sampled nations over time. The approach also increases the robustness and consistency of the estimated relationships by isolating the net impact of institutional and regulatory variables on environmental performance.

The baseline specification mode has been decomposed into a set of sequence of interrelated models to isolate mechanisms, test theoretical pathways as well as robustness.

$$CEM_{it} = e_i + \beta_1 GCL_{it} + \beta_3 X_{it} + y_t + e_{it} \quad (2)$$

It strictly investigates the benchmark (climate commitment only) before bringing in governance capacity and control variables.

Similarly, we can develop another model for regulatory capacity; just to determine its effect alone on carbon emission.

$$CEM_{it} = e_i + \beta_1 REG_{it} + y_t + e_{it} \quad (3)$$

It shows separate enforcement of regulatory capacity alone from the commitment of the existing policy.

We then proceed to determine the combine effect of the core independent variables on dependent variable as. These are the joint policy institution orientation.

$$CEM_{it} = e_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + y_t + e_{it} \quad (4)$$

This also confirms whether the two variables stated are important in the study and the degree of their importance simultaneously.

Also, to determine the interaction effects; which in most cases are referred to as core mechanisms:

$$CEM_{it} = \alpha_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + \beta_3 (GCL_{it} x REG_{it}) + y_t + e_{it} \quad (5)$$

It helps to determine the regulatory capacity conditions and effectiveness of the climate commitment; it means β_3 measures how marginal effect of global climate commitment on emission changes as regulatory quality gets better.

The inclusion of the income adjusted and the Environmental Kuznet Curve (EKC) adjusted model can be included respectively:

$$CEM_{it} = \alpha_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + \beta_3 GDP_{PCit} + y_t + e_{it} \quad (6)$$

$$CEM_{it} = \alpha_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + \beta_3 GDP_{PCit} + \beta_4 GDP_{PC}^2{}_{it} + y_t + e_{it} \quad (7)$$

Scale effects have been into account in relation to economic growth; likewise controls as per nonlinear income emissions respectively

The effects of energy consumption, urbanization, are also taken into consideration respectively:

$$CEM_{it} = \alpha_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + \beta_3 ENE_{it} + y_t + e_{it} \quad (8)$$

$$CEM_{it} = \alpha_i + \beta_1 GCL_{it} + \beta_2 REG_{it} + \beta_3 URB_{it} + y_t + e_{it} \quad (9)$$

While (8) isolates the importance of energy consumption, (which in most cases, the main driver of emission), (9) takes into consideration the demographic and spatial effects on emissions

To determine the fully controlled and most comprehensive specification model especially for inference, we have:

$$CEM_{it} = \alpha_{i+} \beta_1 GCL_{it} + \beta_2 REG_{it} + \mathcal{E} \Upsilon k X_{kit} y_t + e_{it} \quad (10)$$

The model 10 can also serve as robustness across emissions intensity measures an even captures climate impacts broader and beyond $co_{2..}$Likewise, (11) delayed impacts of the climate policies can be taken into considerations by lagged model for climate policies:

$$CEM_{it} = \alpha_{i+} \beta_1 GCL_{i,t-1} + \beta_2 REG_{it} + y_t + e_{it} \quad (11)$$

$$CEM_{it} = \alpha_{i+} \Upsilon t + \beta X_{it} + e_{it} \quad (12)$$

$$logCEM_{it} = \alpha_{i+} \beta_1 logGCL_{it} + \beta_2 logREG_{it} + \beta_3 (logGCL_{it} x\ logREG_{it}) + \mathcal{E}^5 \Upsilon k X_{kit} y_t + e_{it} \quad (13)$$

However, in (12) the country time fixed effect can be determined to take cognizance of country specific heterogeneity and common worldwide shocks: Hence, we bring in the log linear panel model which shows the interaction effect in (13) as defined in (1). Also, employing log allows all the coefficients to be interpreted as elasticities which will eventually improve the policy relevance and comparability across the selected countries with different scales of measurement.

The marginal effect, according to (5) we denote:

$$\frac{dlnCEM}{dlnGCL} = \alpha_{i+} \beta_3 lnREG \quad (14)$$

It is important to take cognizance of the robustness model in the study:

$$Log\ CEM_{it} = \alpha logGEMit\text{-}1 + \beta_{1log}\, GCLit\text{-}1 + \beta_{2logREGit} + \beta_3(logGCLit\text{-}1x\ logREG) + \mathcal{E}^5 \Upsilon k X_{kit}\, y_t + e_{it} \quad (15)$$

Since, the effect of GCL depends on REG, the study tests whether the conditional effect holds as the research controls for temporal ordering and emissions.

Also, given that the interaction and baseline models offers the evidence of governance which is contingent on the effectiveness of climatic conditions, the issues concerning potential endogeneity especially those of emission persistence and reverse causality continually relevant in phenomenon of macro panel frameworks. The issue of carbon emissions constitutes another path dependent in the study as a result of infrastructural and industrial factors. Addressing this situation, a dynamic specification (15) taking into consideration a lagged dependent variable is established or estimated among the robustness checks. The study also introduced climate commitments variables with temporal lags to reduce the simultaneity bias, making sure those commitments come in before observed emission outcomes. The GCL and REG has been hold in the dynamic framework to confirm whether the said conditional effects are stable after considering persistence. Such consistency of the established interaction clause across static and dynamic specifications augments and strengthens the causal explanation and interpretations of governance threshold framework noted in this research.

Table 3.1 Description of Variables

VARIABLES	MEASUREMENTS	SOURCE
CEM (carbon Emission)	CO_2 emissions per capita	WDI
GCL (Global climate commitments)	Renewable energy consumption (% of total final energy)	WDI
REG (regulatory capacity)	Regulatory Quality	WGI
GDP(GDP per capita (constant prices)	GDP per capita (Constant 2015 US dollars)	WDI
URB (urbanization)	Urban population (% of total population)	WDI
ENE (energy consumption)	Energy use per capita (Kilograms of oil equivalent per capita)	WDI
(TRD) trade openness	Trade (% of GDP)	WDI
(IVA) industrial value added	Industry value added (% of GDP)	WDI

Author's computation, 2026

The variables employed are carefully selected to achieve the intended objectives of the study. The Co_2 emission per capita which is the dependent variable is policy relevant that captures environmental pressure. It also functions as scale adjusted and desirable for fixed effect estimation. The renewable energy depicts the extent to which nations translate climate agreements into observable effective mitigation actions. Similarly, regulatory quality reflects effective enforcement of environmental policies. While all other control variables including GDP

per capita, urbanization, energy use per capita, trade and industry value added to take cognizance of economic scale, trade openness, energy intensity and structural composition.

Concerning the reduction of potential endogeneity or simultaneity bias between global climate commitment and emissions, the key independent variable has been introduced in lagged form, which makes the approach to also reduce reverse causality issues and aligns with dynamic environmental policy literature.

4.0 Results

Table 4.1 Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	Pr (Skew)	P(Kur)
log_CEMf	320	3.504071	.9450792	0	4.89784	0.0000	0.0004
log_GCLf	320	4.595023	.9553512	0	5.549076	0.0000	0.0000
log_REGf	320	3.99541	.893461	0	5.111988	0.0000	0.0000
log_GDPf	320	4.780207	.9670382	0	5.768321	0.0000	0.0000
log_URBf	320	4.74222	.9603801	0	5.736572	0.0000	0.0000
log_ENEf	320	4.774623	.964124	0	5.762052	0.0000	0.0000
log_IVAf	320	4.700636	.9498375	0	5.69036	0.0000	0.0000
log_trdf	320	4.762497	.9598981	0	5.749393	0.0000	0.0000

Author's computation, 2026.

The descriptive statistics in Table 4.1 shows the summary statistics of the variables employed in the study. The mean result of carbon emissions (log CEMf) is 3.504 with the standard deviation of 0.945 indicate moderation on emission in the region. While the minimum value shows zero (0) with maximum value of 4.897 suggest a substantial cross sectional heterogeneity in carbon emission intensity in the region. Concerning Global climate commitment (logGCLf), the mean value of 4.595 has been reported with a standard deviation of 0.955 which indicate a relatively stable but noticeable variation across the region. Likewise, as regards regulatory quality (logREGf), the mean value of 3.995 has been reported with standard deviation of 0.893, showing moderate institutional differences in the region.

Concerning the control variables: GDP (logGDPf), urbanization (logURBf), energy use (logENEf), industrial value added (logIVAf), and trade openness (logtrdf) all of them display comparable average values from around 4.70 and 4.78 with the standard deviation of around 0.95, indicating a consistent macroeconomic feature throughout the sampled countries with enough variability to support the estimation. The descriptive also shows large cross-country heterogeneity across the employed variables, especially carbon emissions, industrial value added, as well as climate commitments, denoting structural differences in factors such as energy records and institutional maturity among others in the region. The noted dispersions clearly justify the utilization of panel techniques which is capable of considering both within and between country variations in the study.

The results of the normality tests in this study (Skewness/Kurtosis test) reject the null hypothesis of the distribution especially for all the variables because Prob > chi^2 = 0.0000, which suggest that variables are not normally distributed. Yet, lack of normality does not in any way invalidate the regression results because panel estimators such as Fixed Effects in most cases rely solely on large-sample asymptotic properties; also, apart from transforming the variables to logarithmic form, most of the subsequent estimationslike robust estimation or Driscoll–Kraay standard errors also mitigate any bias arising from non-normality. This description of distributional features of the dataset confirms its appropriateness for econometric analysis without reflecting extreme outliers which could distort inference.

Table 4.2 Correlation Statistics

Variables	logCEMf	logGCLf	logREGf	logGDPf	logURBf	logENEf	logIVAf	logtrdf
logCEMf	1.0000							
logGCLf	-0.6025	1.0000						
logREGf	0.1423	-0.1175	1.0000					
logGDPf	-0.0551	0.1853	0.0079	1.0000				
logURBf	0.6680	-0.3654	0.0149	0.0289	1.0000			
logENEf	-0.2171	0.2199	-0.0886	0.1358	-0.2377	1.0000		
logIVAf	0.3622	-0.2354	0.0764	0.0369	0.3409	-0.1930	1.0000	
logtrdf	0.0737	0.1842	-0.1897	-0.0746	0.1913	-0.1453	-0.0197	1.0000

Author's computation, 2026

This result simply reveals that Carbon emissions (logCEMf) exhibit strong and positive correlation with urbanization (log URB) with 0.668 but moderately correlated with industrial value added with 0.362, this indicates that structural transformation and urban development are associated with high emission exposures across the region. On the other hand, carbon emissions indicate strong and negative correlation with global commitment (logGCLf) r= -0.603, suggesting that economies with stronger climate commitments is very likely to record lower emission intensity. Likewise, the use of energy (logENE) shows weak negative associations with emissions through r = -0.217. Similarly, regulatory quality, GDP, and trade openness (logREGf, logGDPf, and logtrdf respectively) indicate weak correlation with carbon emissions; which simply means that it is likely that their effects may require multivariate regression analysis for proper inference.

It can therefore be said that the inter correlations that exists among the independent variables are low to moderate given no coefficient greater that conventional multicollinearity threshold of around .80 -.90; this clearly indicates that multicollinearity is very unlikely to bias the regression estimates.

Multicollinearity Diagnostic (Variance Inflation Factor)

It is important to also determine the presence of multicollinearity among the independent variables, this makes the study to conduct Variance Inflation Factor (VIF) test after the pooled OLS specification. The result of the test shows that VIF values are below critical thresholds of 5. As shown in table 4.3, the highest VIF recorded for urbanization (logURBf = 1.40), then followed by global climate commitment (logGCLf = 1.38), and the remaining variables record VIF values ranging between 1.06 and 1.22. The mean VIF is 1.21.All these values indicate low degree of linear association among the independent variables; which means that multicollinearity is not an issue in the estimated model.

Table 4.3 Variance Inflation Factor

Variables	VIF	1/VIF
logURBf	1.40	0.712992
logGCLf	1.38	0.725186
logtrdf	1.22	0.821804
logIVAf	1.18	0.850155
logENEf	1.15	0.871070
logGDPf	1.09	0.920703
logREGf	1.06	0.945189
Mean VIF	1.21	

Author's computation, 2026

Hausman Specification Test

The result of Hausman test that has been conducted as shown in Table 4.4 to determine the preferred or appropriate panel estimator. The findings show (χ^2 (7) = 3.80; p = 0.8020) which fail to reject the null hypotheses which states that the difference between the fixed and random effects coefficients is not systematic. This result apparently indicates that the random effects are efficient and consistent in this situation. Hence, the random effect is hereby more efficient and adopted for the preferred baseline estimation, while the fixed effect results are shown for robustness purposes. Also, the main independent variables (GCL and REG) show limited within country temporal changes but high cross-sectional heterogeneity. As this research question is basically comparative across the institutional areas and not strictly temporal within the country adjustments, random effect offers a more appropriate estimator. More so, the study included cluster-robust and Driscoll–Kraay standard errors to reduce issues pertaining heteroskedasticity, serial correlation, and cross-sectional dependence, dealing with or addressing the main inferential constraints commonly related with random effect models. Thus, fixed effects findings are recorded as robustness checks, and the consistency of coefficient signs across estimators further confirm and supports the reliability of random effects specification.

Table 4.4 Hausman Specification Test

Variables	fe	re	Difference	S.E.
logGCLf	-.248725	-.2874881	.0387631	.0274503
logREGf|	.0537107	.0546809	-.0009701	.0025613
logGDPf	.0244714	.0259754	-.001504	.0034697
logURBf	.4366298	.4496546	-.0130248	.0239935
logENEf	.2350431	.1977943	.0372488	.0205979
logIVAf	.0733936	.0730613	.0003323	.0037863
logtrdf	.0313546	.0307814	.0005732	.0025893

Test: Ho: difference in coefficients not systematic
chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 3.80
Prob>chi2 = 0.8020. Where fe = fixed effect; re = random effect & S.E= Standard Error
Author's computation, 2026

4.1 Estimation Results

The result in table 4.5 presents random effects estimation based on the outcome of hausman test. Notably, the wald X^2 statistics of 179.31, $p < 0.001$ denotes that this model is jointly significant, indicating that all the independent variables have very strong explanatory power for variations in carbon emissions in the region over the time of this investigation. This random effect structure is based on the assumption supported by Hausman test findings that the structure of random effect assumes no systematic correlation between the regressors and the unobserved country specific effects. Also, the inter class - coefficient of $p = 0.871$ simply indicates that about 87.1 percent of the total variations in the carbon emissions (dependent variable) is explained or attributable to the time invariant country specific heterogeneity, which apparently justifying the utilization of panel estimator rather than pooled least squared (OLS).

The coefficient of global climate commitment indicates a negative effect on carbon emissions and is highly statistically significant. Given the log log coefficient specification, (logGCL) with ($\beta = -0.534$, $p < 0.01$); this shows that one percent increase in global climate commitment, is associated with approximate 0.53% reduction in carbon emissions all things being equal. This result indicates very strong empirical evidence that regional climate commitments policies, institutional commitments as well as agreements contribute extensively and meaningfully to emission reduction in sus Saharan Africa. The significance and the magnitude of this effect underscore the roles and usefulness of the policy credibility and sustained international climate engagements.

Concerning regulatory capacity (logREG), the model also indicate a negative coefficient but can be said to be marginally significant at 10% level of significance ($p = 0.068$). Similarly, this result indicates that stronger regulatory enforcements in the region are associated with lower emissions, although, there exists a relatively direct effect. Given the weaker probability, in terms of the level of significance, this simply means that only regulatory capacity may not be able to reduce

emission substantially unless it is complemented by effective firm policy implementation mechanisms in the region.

The interaction effect between climate commitment and regulatory capacity indicate a positive and is statistically significant which depicts the presence of moderate relationship ($\beta = 0.057$, $p < 0.05$). This apparently indicates that the marginal effect of climate commitment on emissions can be said to be conditional on the level of regulatory capacity. Strictly speaking, while climate commitment alone reduces emissions, the said emission reducing impact diminishes as regulatory capacity goes up or increasing, indicating that a partial substitution effect. One important plausible meaning is that economies with better and stronger regulatory frameworks may already internalize their environmental standards, thereby decreasing or reducing more marginal benefits from increased commitments. On the other hand, in economies with weaker regulatory capacity, the international climate commitment is likely to play a more pronounced function in emission reductions. Clearly, the existence of a statistically significant interaction is an indication that the coefficient on the commitment cannot be interpreted alone; hence; reinforcing the necessity for marginal effects analysis to take into consideration the heterogeneous effect across the regulatory regions.

Economic growth (logGDPf) shows a positive but insignificant statistical coefficient ($\beta = 0.025$, $p = 0.193$), which implies that within the period under investigation, economic growth does not exhibits a robust independent impact on carbon emissions especially once the institutional as well as structural factors are taken into consideration and are controlled for. This generally may reflect the dominance of sectoral and or energy related drivers over the aggregate income effects. Urbanisation (logURB) shows a very strong positive and highly significant effect on carbon emissions ($\beta = 0.418$, $p < 0.01$). In essence, one percent increase in urbanization (that is increase in population in the urban areas) is associated with forty two percent increase in carbon emissions, which indicates that increase in urban is one of the major drivers of carbon emissions in the region. This result is in line with concentration of transport activities, industrial processes as well as more energy intensive activities in the urban centers.

Concerning trade openness (logtrdf), the result ($\beta = 0.024$, $p = 0.231$) shows a positive but statistically insignificant, suggesting that integration of trade does not independently influence carbon emissions in the region once the energy use, domestic production structures and institutional factors are accounted for. It cannot be emphatically state that the result strongly support pollution haven nor pollution hypothesis in sub-Saharan region. Also, energy consumption (logENEf) shows a positive and significant effect on carbon emissions ($\beta = 0.187$, $p < 0.01$). This indicates that the use of energy in sub Saharan African region, mostly dominated by fossil fuel in the region remains an important pathway through which economic and demographic pressures translate into more emissions in the region. Concerning industrial value added the result indicates a positive and statistically significant in the region during the period under investigation. This result shows that more industrial activities added to carbon emission growth. This is in line with structural transformation channels in developing countries, in situation where industrialization, in most cases precedes widespread adoption of clean technologies

Also, the result of the estimated variance components ($\sigma_u = 0.659$; $\sigma_e = 0.253$) and high rho emphasis the dominance of unobserved country specific features like historical energy infrastructure, geography, and institutional quality in shaping emission trajectories. This not only

reinforces the appropriateness of a panel frameworks but also, validates the appropriateness of and validate random effects specification as a consistent and efficient estimator.

Table 4.5: Random Effects Panel Regression Results (Baseline)

Wald chi2(8) = 179.31						
corr(u_i, X) = 0 (assumed)				Prob > chi2 =	0.0000	
Variables logCEMf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
logGCLf	-.5338411	.1213241	-4.40	0.000	-.771632	-.2960503
logREGf	-.1964528	.1078012	-1.82	0.068	-.4077392	.0148336
logGCLflogREGf	.0569714	.0240068	2.37	0.018	.0099189	.1040239
logGDPf	.0253417	.0194715	1.30	0.193	-.0128217	.063505
logURBf	.4178732	.0618078	6.76	0.000	.2967323	.5390142
logENEf	.1873006	.0513685	3.65	0.000	.0866202	.2879811
logIVAf	.072869	.024723	2.95	0.003	.0244127	.1213252
logTRDf	.0243139	.0203117	1.20	0.231	-.0154962	.0641241
cons	2.246352	.825004	2.72	0.006	.6293735	3.86333
sigma_u	.65911916					
sigma_e	.25326544					
rho	.87134823	(fraction of variance due to u_i)				

Authors computation, 2026.

The Cluster-robust random-effects specification otherwise known as preferred random effects GLS estimation has been selected as shown in Table 4.6 for the study due to the Hausman specification outcome. This model has been estimated by employing cluster robust standard errors especially at country level to take into consideration for within panel dependence as well as heteroskedasticity. As stated in the result, the Wald χ^2 statistic ($\chi^2 = 44.03$, $p < 0.001$) confirms that the regressors are jointly significant, which indicate strong independent power of the model. Also, the result confirms the inter class correlation coefficient of p= 0.871 which indicates that about 87.1.percent of the total variations in dependent variable (carbon emissions) is explained by independent variables and is associated to unobserved country specific heterogeneity, confirming the suitability of the panel framework over pooled estimation.

The coefficient of global climate commitment (logGCLf), ($\beta = -0.534$, $p = 0.040$) exhibits a negative and significant effect on carbon emission. In terms of elasticity, the result indicates that a 1% increase in climate commitment is attributable to 0.53 percent reduction in carbon emission (all other factors remain constant). This shows the support for effectiveness of climate related factors, institutional and policy engagement and considerations in reducing emissions across the region.

In terms of the regulatory capacity (logREGf), the result shows (($\beta = -0.196$, $p = 0.341$) a negative and insignificant coefficient indicating on average, the regulatory strength in isolation does not exert direct and independent effect on emissions. The statistical insignificant of the impact shows that the regulatory institutions may work solely through the interaction with climate policies rather than as an isolated mechanism.

Concerning the interaction effect that exists between the global climate commitment and regulatory capacity, (Climate Commitment × Regulatory Capacity) ($\beta = 0.057$, $p = 0.246$) the result shows a positive but insignificant, especially in cluster robust specification. This implies insufficient evidence of a statistically strong moderating impact at the conventional levels most especially when relying mainly on the coefficient inference, this also confirms the presence of the interaction terms that changes the interpretation of the main impact of the climatic commitment.

It is also very important to point out that in the models involving interaction clause, the significance of the interaction coefficient in isolation does not fully capture the conditional relationship. This simply implies that the marginal impact of the commitment needs to be evaluated across different categories and levels of regulatory capacity by employing marginal effect analysis. This therefore, encourage the presentation of average marginal effects in the next subsection to evaluate conditional influence more appropriately.

Concerning Economic growth (logGDPf) this variable shows a positive but insignificant effect on carbon emission ($\beta = 0.025$, $p = 0.379$), it indicates that income growth by it self does not systematically drive emissions especially when urban, institutional and energy related factors are taken into consideration. Similarly, urbanization (logURBf) shows a positive but statistically insignificant ($\beta = 0.418$, $p = 0.283$) given clustered robust errors. Despite, the sign is in line with theoretical expectations concerning urban energy driven demand situations; it depicts that the emission impact of urbanization exhibits heterogeneity which may be absorbed by country specific featured as captured by random effects. In terms of Energy consumptions (logENEf), the result indicates a positive and weakly statistical significant effect n emissions in the region ($\beta = 0.187$, $p = 0.084$) suggesting that increase energy consumption continually represents a vital channel through which economic activities added to carbon emissions, denoting the continued dominance of carbon intensity sources in SSA. Industrial value added (log_IVAf**)** and Trade Openeness (log_trdf) together show a positive and insignificant coefficients, indicating that their direct impacts on emissions are not all that robust especially once institutional and energy-related controls are taken into consideration.

The result exhibits the dominance of unobserved country specific effects with $p = 0.871$ indicating the role of structural and institutional features towards shaping emission trajectories. Although, random-effects in the previous model provides an efficient baseline estimate, yet, the inclusion of interaction effect terms make it compulsory to move beyond coefficient level interpretation.

Table 4.6 Cluster-robust random-effects specification

Wald chi2(8) = 44.03 corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0000
(Std. Err. adjusted for 20 clusters in id)

Variables		Robus				
logCEMf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_GCLf	-.5338412	.2596257	-2.06	0.040	-1.042698	-.0249841
log_REGf	-.1964529	.2062994	-0.95	0.341	-.6007923	.2078865
c.log_GCLf#c.log_REGf	.0569714	.0491068	1.16	0.246	-.0392762	.153219
log_GDPf	.0253417	.0287821	0.88	0.379	-.0310702	.0817536
log_URBf	.4178732	.389146	1.07	0.283	-.3448389	1.180585
log_ENEf	.1873007	.1084997	1.73	0.084	-.0253548	.3999561
log_IVAf	.072869	.0719903	1.01	0.311	-.0682295	.2139674
log_trdf	.0243139	.0241477	1.01	0.314	-.0230146	.0716425
_cons	2.246352	2.61265	0.86	0.390	-2.874349	7.367053

sigma_u .65911917
sigma_e .25326544
rho .87134824 (fraction of variance due to u_i)

Author's computation, 2026

Marginal Effects Transition

It is important to note that the inclusion of interaction effect between climate commitment and regulatory capacity on climate commitment, basically on coefficient does not represent a constant partial effect only as more interpretation is needed through an average marginal effects and graphical analysis, which explicitly show how the emission-reducing effect of climate commitment differs across different categories and levels of regulatory capacity as displayed in the next subsections.

Average Marginal Effects (AMEs)

Table 4.7 depicts average marginal effects (AMEs) of global climate commitment (logGCLf) on carbon emissions (logCEMf), which is conditional on the selected levels of regulatory capacity (logREGf). According to the result in the table, the AMEs shows that global climate commitment has a significant and economically adverse impact on carbon emissions across the region given all the observed levels of regulatory capacity. Importantly, as shown in the table, a 1 percent rise in climate commitment (logGCLf) decreases emissions by approximately 0.33%, 0.29%, and 0.27% at low, moderate, and high regulatory capacity levels, respectively. Despite that the magnitude of the effect reduces slightly as the regulatory quality gets better or improves, the confidence intervals still remain strictly negative across all level, confirming the robustness of the mitigation effect. These results indicate that climate commitment is one of the important

yardsticks contributing to emission reduction irrespective of institutional power or strength, with somewhat stronger marginal impacts in situations of weaker regulatory environments.

Table 4.7 Average marginal effects

Model VCE: Robust
Expression: Linear prediction, predict () dy/dx w.r.t: logGCLf
1._at :logREGf = 3.58
2._at :logREGf = 4.23
3._at :logREGf = 4.66

Delta-method

dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
logGCLf					
_at					
1	-.3298835	.1252401	-2.63	0.008	-.5753496	-.0844173
2	-.292852	.1136876	-2.58	0.010	-.5156756	-.0700284
3	-.2683543	.1105385	-2.43	0.015	-.4850059	-.0517028

Author's computation, 2026

Conditional Marginal Effects of Global Climate Commitment Across Levels of Regulatory Capacity

Figure 4.1 shows the conditional marginal effects of the global climate commitment logGCLf on carbon emissions (logCEMf) across varying level of observed range of regulatory capacity (logREGf), with 95% confidence intervals. This graphical figure also corroborates the marginal effects table presented earlier and confirms that emission reduction effect of climate commitment is robust to institutional heterogeneity. The figure also shows that the marginal effect remains and confirms negative and statistically significant too throughout the observed regulatory range. Although, it has been pointed out here that the magnitude of the impact of reduction of emission declines modestly as regulatory capacity increases, yet the confidence intervals remain strictly below zero, suggesting robust reduction effects irrespective of institutional strength.

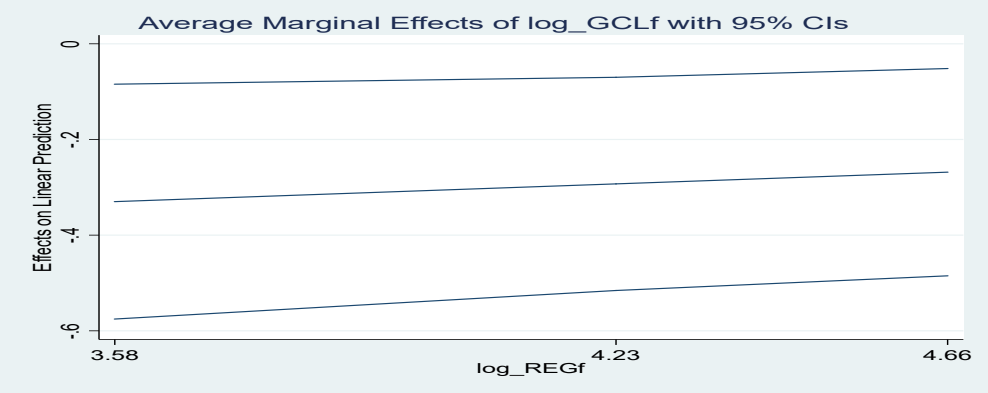


Figure 4.1.Conditional Marginal Effects of Global Climate Commitment Across Levels of Regulatory Capacity

Combined Robustness

Table 4.8 summarizes alternative estimators to confirm and verify the robustness of the baseline random effects outputs. It is clearly seen from the table that columns 1- 4 show pooled OLS, fixed effects, conventional random effects, and Driscoll–Kraay estimations, respectively. The sign and the magnitude of the climate commitment coefficient remain consistent across specifications, which confirms the core results are not estimator-dependent.

Table 4.8 Combined Robustness

	(1) Pooled OLS	(2) Fixed Effects	(3) Random Effects	(4) Driscoll-Kraay
log_GCLf	-1.018***	-0.501***	-0.534***	-0.501**
	(-5.17)	(-4.03)	(-4.40)	(-2.73)
log_REGf	-0.463**	-0.206*	-0.196*	-0.206
	(-2.51)	(-1.89)	(-1.82)	(-1.48)
log_GCLf_log_REGf	0.132***	0.059**	0.057**	0.059
	(3.13)	(2.42)	(2.37)	(1.56)
log_GDPf	0.024	0.023	0.025	0.023
	(0.66)	(1.18)	(1.30)	(1.66)
log_URBf	0.437***	0.400***	0.418***	0.400***
	(10.66)	(6.01)	(6.76)	(5.42)
log_ENEf	0.003	0.225***	0.187***	0.225***
	(0.08)	(4.09)	(3.65)	(6.35)
log_IVAf	0.105***	0.073***	0.073***	0.073
	(2.80)	(2.94)	(2.95)	(1.61)
log_trdf	0.072*	0.025	0.024	0.025
	(1.91)	(1.21)	(1.20)	(1.47)
_cons	4.578***	2.005**	2.246***	2.005**
	(4.58)	(2.37)	(2.72)	(2.26)
Observations	320.000	320.000	320.000	320.000
R-squared	0.628	0.352		

t statistics in parentheses, t statistics in parentheses, *, **, *** denote significance at 10%, 5%, and 1% $p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$.

Author's computation, 2026

Robustness Results Checks

Table 4.9 shows the result of cluster-robust standard errors that has been applied in the study, there exists a negative lagged global climate commitment which remains economically meaningful but becomes marginally significant at 10 percent level. The interaction effect maintains its sign but losses its conventional significance. This indicates that while the direction

of the moderating effect is stable, inference is very sensitive to clustering across a relatively small number of countries. This result simply suggests a stable coefficient that also confirms that the core relationship is not driven by heteroskedasticity.

Table 4.9 Robust Standard Error Test (Re Robust)

Variables (1)	**RE(2)**	**RE Robust**
L.GCL	−0.450***	−0.450*
REG	−0.170*	−0.170
L.GCL × REG	0.051**	0.051
Controls	Yes	Yes
Countries	20	20
Observations	300	300

Author's computation, 2026 .p<0.10,** p<0.05,*** p<0.01

Cross-Sectional Dependence Test

The study examines whether residuals are contemporaneously correlated across the economies in consideration, hence, the study employed Pesaran (2004) cross-sectional dependence (CD) and the result shows that CD statistic = 1.456 and p-value = 0.145. This result indicated that the p-value is greater than significance levels ($p > 0.10$), and we fail to reject the null hypothesis of cross-sectional independence. This impliedly means that the residuals are not significantly correlated across countries, meaning that unobserved common shocks do not materially bias the baseline panel estimations.

Other Estimation

The result in Table 4.9 presents the test of Breusch pagan multiplier that strongly rejects the null hypothesis of no panel effects that ($\chi^2 = 1316.11$, $p < 0.01$) which depicting the existence of significant country specific heterogeneity. This result also establishes that pooled OLS is not appropriate and still justifies the utilization of panel estimation techniques too.

Table 4.9 Breusch–Pagan LM Test

Estimated results:		
Var	sd = sqrt(Var)	
log_CEMf	.8395921	.9162926
e	.052911	.2300239
u	.408426	.6390821
Test:Var(u) = 0		
chibar2(01) = 1316.11		
Prob > chibar2 = 0.0000		

Author's computation, 2026

Heterogeneity Analysis

Table 4.10 summarizes the analysis of the heterogeneity where the study has split the observations into four (4) quartiles where each quartile contains eighty (80) observations. The distribution of log_GCLf displays clear heterogeneity. Also, lower quartiles (one and two) display more changes and variability and skewed distributions, depicting that some economies as well as observations lag significantly in global climate commitment. Also, higher quartiles three and four are more homogeneous, tightly clustered, and symmetric, indicating that advanced performers have the same or similar logGCLf levels. This pattern shows structural differences in commitment across the spectrum.

Table 4.10 Heterogeneity Analysis using Quartiles of logGCLf

Quartile (p50)	N	Mean	Median	SD	Min	Max	Skewness	Kurtosis
1	80	3.237	3.497	0.911	0	4.205	-1.335	4.473
2	81	4.632	4.663	0.209	4.220	4.927	-0.326	1.928
3	80	5.119	5.121	0.093	4.934	5.252	-0.202	1.861
4	79	5.401	5.398	0.085	5.257	5.549	0.028	1.858

Author's computation, 2026

Discussion of findings

The study employs the baseline random-effects panel regression results given strong reasons to provide essential empirical insights into the determinants of carbon emissions in Sub-Saharan Africa and the role of institutional and policy mechanisms in shaping environmental outcomes. The adoption of the random-effects (RE) estimator apart from Hausman test validity, assumes that unobserved country-specific heterogeneity is uncorrelated with the explanatory variables, thereby allowing efficient estimation in a multi-country panel framework. This approach is mostly suitable for cross-country environmental analyses where structural differences across economies exist but are not perfectly observable. The Wald chi-square test's statistical significance ($\chi^2 = 179.31$, $p < 0.01$) suggests that the independent variables, when considered together, explain the observed differences in carbon emissions across the countries studied. More so, the substantial intra-class correlation coefficient ($\rho = 0.8713$) indicates that a considerable portion of the variation in carbon emissions is due to factors specific to each country. Therefore, this finding highlights the importance of considering the differences within Sub-Saharan African economies when assessing the environmental effects of institutional and policy-related factors.

The inverse correlation observed between global climate commitment and carbon emissions suggests a substantial decrease, implying that a more robust adherence to international climate agreements fosters enhanced environmental performance within the region. The finding is in line with the increasing study relating to the influence of global climate governance on environmental outcomes at the national level. In particular, this finding is consistent with the evidence put forth by Pal et al. (2026), who, employing a random-effects panel estimation approach, demonstrate that stronger climate policy commitments and governance mechanisms contribute greatly to emission mitigation. Similarly, recent policy-oriented research provides that climate policy instruments and carbon regulation mechanisms show a crucial significance in guiding nations toward greener development trajectories (Zhou & Lin, 2025; Bian et al., 2024). This simply

means that participation in global climate agreements can exert meaningful environmental effects when countries translate international commitments into domestic policy actions and regulatory measures.

More so, the findings also show that the direct effect of regulatory capacity is only weakly significant, implying that the institutional frameworks alone may not automatically lead to improved environmental outcomes. This basically reveal that though, the regulatory bodies in respective countries and institutions are important, yet, their independent effect may be restricted by factors like administrative inefficiencies, implementation challenges, and broader governance constrains that characterize many developing nations. This slightly contrasts with the findings of Javed et al. (2024), who revealed that strong institutional quality and governance capacity significantly increase environmental sustainability through improved policy enforcement and technological adoption. The characteristics of relatively weaker institutional effect observed in this study may therefore show the continuous institutional gaps and policy implementation issues across many SSA countries. Similar observations are also shown by Ahakwa et al. (2023) and Amin et al. (2023), who argue that environmental policies in developing regions always suffer from weak institutional implementation, thereby restricting their effectiveness in reducing environmental degradation.

Concerning the interaction impact, the interaction between global climate commitment and regulatory capacity is positive and statistically significant, implying that the concerned regulatory institution moderates the relationship between international climate commitments and carbon emissions. This implying that nations with stronger regulatory structures (as we have in in most developed countries) are better stationed to translate global climate commitments into effective emission reduction outcomes. Differently, the environmental significance of international climate cooperation depend solely on domestic institutional quality. The result reinforces the argument in the environmental governance studies that institutional capacity serves as an important enabling mechanism for effective climate policy enforcement and implementation (Tallberg, 2021; Zürn, 2018). This finding is also in line with the broader perspective that climate governance operates through multi-level institutional arrangements in which international commitments interact with domestic regulatory frameworks to influence environmental outcomes.

Importantly, to submit a concrete supportive contribution through a theoretical perspective, it is also clear the results indicate an essential contribution of the study by moving beyond the traditional Environmental Kuznets Curve (EKC) framework toward the New Institutional Economics (NIE) perspective. It is clearly clear that EKC studies largely concerns environmental outcomes to the income and environment relationship (Ozcan et al., 2018; Li et al., 2024), the findings of this study indicate that institutional mechanisms most especially regulatory capacity and policy commitments, display a more decisive role in shaping carbon emission dynamics in Sub-Saharan Africa. The NIE side specifically is in support of role the structures, institutional quality, and regulatory effectiveness in determining policy outcomes. The empirical evidence shown in the study indicate that environmental sustainability in developing nations may depend less on income driven structural transformation and more on the effectiveness of institutional frameworks that guide environmental policy implementation.

Concerning the employed control variables in the study, for instance urbanization exhibits a strong and positive relationship with carbon emissions, this simply implies that rapid increasing

cities significantly contributes to environmental pressure in Sub-Saharan Africa. This result is in line with previous researches that highlight the environmental consequences of rapid expanding urbanization in developing countries, especially through more energy demand, transportation network activities, and industrial concentrations (Nathaniel & Khan, 2020; Pata et al., 2023). The more and more people reside in urban areas, it is expected that the demand for infrastructure, housing, and transportation will increase, thereby intensifying energy consumption and carbon emissions.

Also, following the result of increasing urbanization is more energy consumption which also shows a positive and statistically significant effect on emissions, likewise confirming the dominant role of fossil-fuel-based energy systems in driving environmental degradation in the country. The result corroborate with the broader energy-environment studies, which reiterate that energy intensity and dependence on non-renewable energy sources remain one of the main drivers of carbon emissions in developing countries (Alola & Adebayo, 2023). it is possible for emission level to keep increasing, unless there is a transition toward a cleaner and more efficient energy technologies, this is because rising energy demand are always associated with economic development especially in developing nations.

The finding also show that industrial value added significantly increases carbon emissions, which imply that industrial increase in SSA remains largely carbon intensive. The study noted that this supports the findings of Guo et al. (2021), that demonstrate that industrial development can in most cases increase environmental pressure when technological innovation and green production practices are limited in supply. Concentration of industries in many developing nations in most instances relies on energy-intensive production methods, thereby increasing carbon emissions unless accompanied by technological upgrading and environmental regulation.

Contrarily, economic growth and trade openness appear statistically insignificant in the baseline model, this simply show that their environmental effects may depend on structural factors like environmental policies, technological progress, and the composition of trade flows. Most of the previous existing research reported mixed evidence concerning the growth environment nexus, emphasizing that the environmental results of economic expansion are highly dependent on energy structure, institutional quality, and technological innovation (Li et al., 2024; Dai et al., 2025). The findings of this study underscore that global climate commitments can contribute significantly to emission reduction in Sub-Saharan Africa, but their effectiveness depends critically on domestic regulatory capacity and broader structural conditions.

Conclusion

This research examined the relationship that exists between global climate commitment, regulatory capacity, and carbon emissions in SSA over the period 2009–2024. Utilizing panel random-effects framework for the estimation, the results shows that stronger global climate commitments are related or associated with reductions in carbon emissions across the region. However, the efficiency as well as the effectiveness of the commitments is significantly conditioned by the domestic regulatory capacity. Importantly, the findings show a statistically significant interaction effect, implying that the regulatory institutions function as a critical transmission mechanism through which international climate commitments translate into measurable environmental outcomes. In the economy where regulatory oversight seems remains weak, international climate commitments may generate limited reduction effects.

The results also contribute to the climate governance studies by shifting the analytical focus from the traditional income-driven Environmental Kuznets Curve (EKC) framework toward a New Institutional Economics (NIE) perspective. The evidence indicates that environmental outcomes in SSA region are influenced less by income changes and more by the strength of regulatory institutions and policy enforcement capacity. This vividly underscores the presence of continuous policy implementation gap that constrains the region's ability to fully realize the reduction potential of international climate commitments. Considering the policy standpoint, the findings indicate the role of enhancing institutional coordination, strengthening regulatory capacity, and reinforcing enforcement mechanisms to increase the environmental effectiveness of global climate governance in SSA. As the region continues to exhibits rapid urbanization and industrial expansion, aligning international climate commitments with robust domestic governance frameworks will be essential for enabling low-carbon development pathways while minimizing the risk of long-term fossil-fuel lock-in.

This study advances understanding of how international climate agreements are implemented through institutions to achieve environmental outcomes; however, its analysis is constrained by its reliance on macro-level governance indicators. These indicators might not adequately reflect the complex dynamics of regulatory enforcement within Sub-Saharan African economies. Subsequent research could benefit from the inclusion of disaggregated institutional metrics and sector-specific emissions data. This would enable a more detailed examination of the pathways through which regulatory capacity influences the efficacy of climate policy.

Declaration section

Data Availability Statement
The datasets analyzed during the current study are publicly available from the World Development Indicators (WDI) database of the World Bank (https://databank.worldbank.org/source/world-development-indicators) and the Worldwide Governance Indicators (WGI) database (https://info.worldbank.org/governance/wgi/). All variables used in this study were obtained from these databases and are publicly accessible.

The datasets analyzed in this study are available from the corresponding author on reasonable request.

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