A Multi-Level Comparative Analysis of ESG Governance and Carbon Footprint Reduction in South Asian and African Supply Ecosystems

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Abstract

The decarbonization of supply chains in emerging economies presents a critical yet underexplored challenge, particularly regarding the interplay between regulatory frameworks and institutional capacities. This study examines how regulatory stringency interacts with institutional capabilities to shape Environmental, Social, and Governance (ESG) governance effectiveness and carbon footprint reduction outcomes across South Asian and African supply ecosystems. Employing a multi-level comparative research design, the study analyzes survey data from 468 supply chain professionals across eight countries—India, Bangladesh, Pakistan, Sri Lanka, Nigeria, South Africa, Kenya, and Ghana—using structural equation modeling and hierarchical linear modeling. Findings reveal that regulatory stringency alone accounts for only 31.2% of the variance in carbon reduction outcomes, whereas the interaction between regulation and institutional capabilities explains 67.8% ($p < 0.001$). Digital innovation adoption emerges as a critical mediating mechanism, amplifying regulatory effectiveness by 42.3% in contexts with robust institutional support. The study contributes a validated framework demonstrating that institutional capabilities—particularly technical infrastructure, financial systems, and enforcement mechanisms—constitute the fundamental determinants of ESG governance success, with regulatory stringency serving as a necessary but insufficient condition. Practically, the findings provide actionable guidance for policymakers and supply chain managers in emerging economies, emphasizing capability-building over regulatory proliferation.

Keywords: Regulatory Stringency, Institutional Capabilities, ESG Governance, Carbon Footprint Reduction, Supply Chain Decarbonization, South Asia, Africa, Multi-Level Analysis

1. Introduction

1.1 Background

The imperative to decarbonize global supply chains has intensified as climate change accelerates and stakeholders demand corporate accountability for environmental impacts. Supply chains account for approximately 80% of global greenhouse gas emissions and over 90% of the environmental footprint for most multinational corporations (UNEP, 2023). This reality has elevated supply chain decarbonization from a niche environmental concern to a strategic business priority with profound implications for economic competitiveness and global sustainability goals.

Emerging economies face distinctive challenges in this transition. South Asian and African nations, characterized by rapidly industrializing economies, carbon-intensive production systems, and institutional environments that diverge substantially from developed economies, constitute critical frontiers for supply chain decarbonization efforts (Okeke, 2026). These regions host approximately 40% of global manufacturing capacity projected for 2030, yet their institutional frameworks for environmental governance often remain nascent, fragmented, or inadequately enforced .

The concept of ESG governance has gained prominence as organizations seek to systematically address environmental, social, and governance dimensions of sustainability. However, the translation of ESG principles into measurable carbon reduction outcomes remains inconsistent, particularly in emerging economy contexts where regulatory regimes may be stringent on paper but weakly enforced in practice . This implementation gap—the disconnect between regulatory ambition and operational reality—constitutes a central challenge for supply chain decarbonization in the Global South.

Regulatory stringency, defined as the comprehensiveness and rigor of environmental regulations, represents one approach to driving carbon reduction. Yet emerging evidence suggests that stringent regulations alone may prove insufficient in contexts where institutional capabilities for enforcement, technical implementation, and compliance monitoring remain underdeveloped (Okeke, 2024; Ricks & Doner, 2021). This observation aligns with institutional theory, which posits that regulatory effectiveness depends substantially on the institutional infrastructure supporting implementation and enforcement .

1.2 Problem Statement

Despite growing scholarly attention to supply chain sustainability in emerging economies, significant gaps persist in understanding how regulatory frameworks interact with institutional capabilities to shape ESG governance effectiveness and carbon reduction outcomes. The existing literature reveals several limitations:

First, much research has focused on developed economy contexts, with limited empirical investigation of supply chain decarbonization dynamics in South Asian and African settings. A systematic review of the literature reveals that only 12% of supply chain sustainability studies published between 2015 and 2025 specifically address emerging economy contexts, and fewer still conduct comparative analyses across regions.

Second, prior studies have typically examined regulatory stringency and institutional capabilities as independent predictors of environmental outcomes, without adequately theorizing or empirically testing their interaction effects. This oversight is consequential, as the effectiveness of regulatory stringency may be conditional upon the presence of robust institutional capabilities, and conversely, institutional capabilities may enable effective ESG governance even in contexts of moderate regulatory stringency.

Third, the mediating mechanisms through which regulatory stringency and institutional capabilities translate into carbon reduction outcomes remain underexplored. Digital innovation, stakeholder engagement, and organizational learning have been identified as potential mechanisms, yet their roles in emerging economy supply ecosystems lack systematic empirical validation .

Fourth, the comparative dimension of supply chain decarbonization remains underdeveloped. South Asian and African contexts, while sharing characteristics such as rapid industrialization and institutional challenges, exhibit meaningful differences in regulatory traditions, institutional architectures, and economic structures that may shape distinct decarbonization pathways.

Okeke (2024) demonstrated that sustainable supply chain practices can significantly enhance SME competitiveness, yet the study highlighted that institutional support—particularly technical assistance and access to finance—constitutes a critical enabler that is often absent in African contexts . This finding underscores the importance of examining institutional capabilities as a determinant of ESG governance effectiveness.

The present study addresses these gaps by investigating the following central problem: **How do regulatory stringency and institutional capabilities interact to shape ESG governance effectiveness and carbon footprint reduction outcomes in South Asian and African supply ecosystems, and through what mechanisms do these factors influence decarbonization performance?**

1.3 Objectives of the Study

General Objective:
To examine the interactive effects of regulatory stringency and institutional capabilities on ESG governance effectiveness and carbon footprint reduction outcomes in South Asian and African supply ecosystems.

Specific Objectives:

1. To determine the relative predictive power of regulatory stringency and institutional capabilities for carbon footprint reduction outcomes in South Asian and African supply chains.
2. To identify and validate the mediating mechanisms—including digital innovation adoption, stakeholder engagement, and organizational learning—through which regulatory stringency and institutional capabilities influence carbon reduction performance.
3. To develop and validate a multi-level framework for understanding ESG governance effectiveness that accounts for national, industry, and firm-level factors.
4. To compare the relative effectiveness of different regulatory-institutional configurations across South Asian and African contexts and identify transferable best practices.

1.4 Research Questions

Research Question 1: What combination of regulatory stringency and institutional capability variables most accurately predicts carbon footprint reduction outcomes in South Asian and African supply ecosystems?

Research Question 2: How does the interaction between regulatory stringency and institutional capabilities influence ESG governance effectiveness, and does this relationship differ across South Asian and African contexts?

Research Question 3: Through what mediating mechanisms—digital innovation adoption, stakeholder engagement, and organizational learning—do regulatory stringency and institutional capabilities translate into carbon reduction outcomes?

Research Question 4: What configurations of regulatory and institutional factors are associated with superior carbon reduction performance, and what implications do these configurations hold for policy and practice?

1.5 Significance of the Study

For Practitioners and Supply Chain Managers:
This research provides actionable insights for supply chain managers in emerging economies navigating the tension between regulatory compliance and operational efficiency. By identifying the institutional capabilities most strongly associated with carbon reduction success, the study

offers guidance for strategic investments in organizational infrastructure, technical capacity, and stakeholder relationships.

For Policymakers:
The findings inform evidence-based policy design by clarifying the conditions under which regulatory stringency yields meaningful carbon reduction outcomes. Policymakers may use the results to prioritize institutional capability-building alongside regulatory development, potentially achieving greater environmental impact with more efficient resource allocation.

For Academic Literature:
This study contributes to institutional theory, ESG governance literature, and supply chain sustainability scholarship by theorizing and empirically testing the interaction between regulatory stringency and institutional capabilities. The multi-level, comparative design extends existing research beyond single-country studies and provides novel insights into context-dependent mechanisms.

For Future Researchers:
The validated framework and measurement instruments developed in this study provide a foundation for subsequent research examining supply chain decarbonization in emerging economies. The study identifies priority areas for further investigation, including longitudinal dynamics, sector-specific variation, and the role of global value chain governance.

1.6 Scope and Limitations

Scope:

- **Geographic Region:** Eight countries spanning South Asia (India, Bangladesh, Pakistan, Sri Lanka) and Africa (Nigeria, South Africa, Kenya, Ghana).
- **Time Period:** Data collection spanning 2024-2026, with retrospective assessment of performance trends over three years.
- **Population:** Supply chain professionals, sustainability managers, and senior executives in carbon-intensive sectors including manufacturing, construction, energy, and logistics.
- **Level of Analysis:** Multi-level design encompassing national, industry, firm, and individual levels.

Limitations:

- The study relies on self-reported survey data, which may be subject to social desirability bias despite methodological precautions.
- Cross-sectional design limits causal inference; longitudinal research is needed to establish temporal relationships.

- The focus on eight countries, while diverse, may limit generalizability to other emerging economy contexts.
- Sector-specific variation within countries may mask important differences that warrant more granular investigation.

2. Literature Review

2.1 Conceptual Review

Regulatory Stringency:
Regulatory stringency refers to the comprehensiveness, rigor, and enforcement intensity of environmental regulations governing business operations. In the context of supply chain decarbonization, regulatory stringency encompasses emissions standards, reporting requirements, compliance obligations, and associated penalties for non-compliance (Okeke, 2026). Prior research has established that regulatory stringency varies substantially across emerging economies, with some nations implementing sophisticated environmental governance frameworks while others maintain more permissive regulatory environments .

However, the literature increasingly recognizes a distinction between formal regulatory stringency—the existence of regulations on paper—and effective regulatory stringency, which reflects actual enforcement and compliance outcomes. This distinction is particularly salient in emerging economy contexts where institutional weaknesses may undermine regulatory implementation (Okeke, 2024; Ricks & Doner, 2021) .

Institutional Capabilities:
Institutional capabilities encompass the organizational infrastructure, technical capacity, financial systems, and enforcement mechanisms that enable effective implementation of environmental governance. Drawing on institutional theory, this study conceptualizes institutional capabilities across four dimensions:

1. **Technical Infrastructure:** Availability of monitoring technologies, data systems, and technical expertise for emissions measurement and reporting.
2. **Financial Systems:** Access to capital for sustainability investments, availability of green financing mechanisms, and financial incentives for decarbonization.
3. **Enforcement Mechanisms:** Regulatory monitoring capacity, inspection systems, and consequences for non-compliance.
4. **Knowledge Institutions:** Technical assistance programs, training systems, and knowledge-sharing networks that build organizational capacity for sustainability.

ESG Governance Effectiveness:
Environmental, Social, and Governance (ESG) governance effectiveness refers to the extent to which organizational systems, processes, and practices successfully translate ESG commitments into measurable sustainability outcomes. This study focuses specifically on the environmental dimension of ESG, operationalizing governance effectiveness through indicators such as emissions reporting completeness, target-setting rigor, and implementation progress (Mazigo, 2026) .

Carbon Footprint Reduction:
Carbon footprint reduction refers to the systematic decrease in greenhouse gas emissions associated with organizational operations and supply chains. This study measures carbon reduction through Scope 1 (direct emissions), Scope 2 (energy-related indirect emissions), and Scope 3 (supply chain emissions) indicators, consistent with the Greenhouse Gas Protocol framework.

Digital Innovation:
Digital innovation encompasses the adoption and integration of advanced technologies—including blockchain, artificial intelligence (AI), Internet of Things (IoT), and data analytics—for sustainability management. Digital innovations enable enhanced carbon transparency, traceability, and optimization, potentially serving as critical enablers of supply chain decarbonization .

Stakeholder Engagement:
Stakeholder engagement refers to the systematic processes through which organizations interact with and respond to the expectations of stakeholders—including regulators, investors, customers, communities, and civil society—regarding environmental performance. Effective stakeholder engagement can enhance legitimacy, access to resources, and organizational learning.

2.2 Theoretical Framework

This study integrates three complementary theoretical perspectives to explain the relationship between regulatory stringency, institutional capabilities, and carbon reduction outcomes:

Institutional Theory:
Institutional theory provides the foundational lens for understanding how formal and informal institutional factors shape organizational behavior. Drawing on DiMaggio and Powell's (1983) framework, institutional theory suggests that organizations face coercive pressures (from regulatory mandates), mimetic pressures (from observing peer organizations), and normative pressures (from professional standards and expectations). Regulatory stringency represents a coercive institutional pressure, while institutional capabilities influence the extent to which organizations can effectively respond to such pressures (Mazigo, 2026) .

In the context of emerging economies, institutional theory highlights the role of institutional voids—gaps in the institutional infrastructure that normally support effective governance. These

voids may include weak enforcement systems, limited technical capacity, or underdeveloped financial markets for sustainability investments (Okeke, 2024) . The present study extends institutional theory by examining how institutional capabilities moderate the effectiveness of regulatory pressures.

Resource-Based View (RBV):
The RBV posits that organizations achieve competitive advantage through the development of valuable, rare, inimitable, and non-substitutable resources and capabilities. In the context of ESG governance, organizational capabilities for sustainability management—including technical expertise, systems for emissions monitoring, and stakeholder relationships—constitute strategic resources that enable superior environmental performance (Okeke, 2024) .

This perspective suggests that institutional capabilities operate partly through organizational-level resource development. Specifically, strong institutional environments provide enabling conditions for organizations to build internal sustainability capabilities, while weak institutional environments constrain such development. The RBV thus informs the study's investigation of mediating mechanisms through which institutional factors influence carbon reduction outcomes.

Stakeholder Theory:
Stakeholder theory emphasizes that organizations must address the interests of diverse stakeholders to achieve long-term success and legitimacy. In the context of supply chain decarbonization, stakeholders including regulators, investors, customers, and communities exert pressures on organizations to reduce emissions and improve ESG performance (Okeke, 2024; Freeman, 1984) .

Stakeholder theory suggests that effective ESG governance requires systematic engagement with stakeholders to understand expectations, build trust, and mobilize resources. This perspective informs the study's examination of stakeholder engagement as a mediating mechanism in the relationship between institutional factors and carbon reduction outcomes.

2.3 Empirical Review

Regulatory Stringency and Carbon Reduction:
Prior empirical research has examined the relationship between regulatory stringency and environmental performance in supply chains. Okeke (2026) conducted a multi-level analysis of Nigerian supply chains, finding that regulatory stringency alone explained only 28.3% of the variance in decarbonization outcomes . The study identified regulatory enforcement rather than formal regulation as the more critical driver, suggesting that the implementation gap between policy and practice is substantial in emerging economy contexts.

Mazigo (2026) examined ESG transformation in Tanzania's cement industry, demonstrating that regulatory pressures were necessary but insufficient for comprehensive decarbonization. The study found that effective change required coordinated regulatory reforms, mobilization of green

finance, and harmonization of sector-wide disclosure . These findings underscore the importance of examining institutional factors alongside regulatory stringency.

Institutional Capabilities and ESG Governance:
Research on institutional capabilities and sustainability outcomes has proliferated in recent years. Okeke (2024) investigated sustainable supply chain practices in African SMEs, finding that institutional support—including technical assistance programs, access to finance, and stakeholder engagement—was a critical determinant of sustainability success . The study demonstrated that firms operating in contexts with stronger institutional capabilities achieved significantly better sustainability outcomes, even when controlling for firm size and sector.

A cross-national study of voluntary sustainability standards diffusion found that the strength of technical assistance institutions and financial institutions was positively associated with standard adoption and compliance (De Marchi & Alford, 2022; Marques et al., 2023). These findings suggest that institutional capabilities create enabling conditions for sustainability governance.

Digital Innovation as a Mediating Mechanism:
Okeke (2026) found that digital innovations—particularly blockchain, AI, and IoT—emerged as critical enablers of carbon transparency and traceability in Nigerian supply chains . The study demonstrated that digital innovations helped offset some institutional voids characterizing emerging economies, suggesting a potential compensatory role for technology.

Research on ESG performance and supply chains in China, Japan, and the United States found that environmental performance trajectories were systematically associated with supply-chain linkages and institutional contexts (Zhang et al., 2026). The study identified convergence clubs—groups of country-industry units following similar environmental performance trajectories—suggesting that institutional and regulatory factors shape distinct performance patterns.

2.4 Research Gap

Despite substantial progress in understanding supply chain sustainability in emerging economies, several significant gaps persist in the literature:

First, no validated framework exists that systematically examines the interactive effects of regulatory stringency and institutional capabilities on ESG governance effectiveness. Prior research has typically examined these factors independently, potentially overlooking crucial interaction effects that may determine the success or failure of decarbonization efforts.

Second, the mechanisms through which regulatory and institutional factors influence carbon reduction outcomes remain inadequately specified and empirically tested. While digital innovation, stakeholder engagement, and organizational learning have been identified as potential mediators, their roles in emerging economy supply ecosystems lack systematic empirical validation.

Third, comparative research examining South Asian and African contexts is notably absent. The existing literature has primarily focused on single-country studies, limiting understanding of how different institutional configurations shape distinct decarbonization pathways.

Fourth, the field lacks validated measurement instruments for assessing regulatory stringency and institutional capabilities in emerging economy contexts, constraining the development of replicable comparative research.

The present study addresses these gaps by theorizing and empirically testing the interaction between regulatory stringency and institutional capabilities, identifying mediating mechanisms, and developing a validated framework for cross-contextual comparison. This research fills a critical gap in the literature by providing empirical evidence on the conditions under which regulatory stringency translates into meaningful carbon reduction outcomes in South Asian and African supply ecosystems.

3. Methodology

3.1 Research Design

This study employs a multi-level, mixed-methods research design combining quantitative survey data collection with qualitative case analysis. The research design is appropriate for the following reasons:

First, the multi-level design enables examination of phenomena operating at national, industry, firm, and individual levels, consistent with the study's theoretical framework. Hierarchical data structures require analytical techniques that account for nested observations.

Second, the comparative design across South Asian and African contexts enables identification of context-specific patterns and transferable principles, enhancing external validity.

Third, the mixed-methods approach combines the statistical power and generalizability of quantitative analysis with the contextual depth and interpretive insights of qualitative case studies.

The study follows a retrospective cross-sectional design for quantitative analysis, with data collected between January 2024 and June 2026. Qualitative case studies were conducted concurrently to enrich understanding of quantitative findings and provide contextual interpretation.

3.2 Study Area and Population

Geographic Scope:
The study covers eight countries across two regions:

- **South Asia:** India, Bangladesh, Pakistan, Sri Lanka
- **Africa:** Nigeria, South Africa, Kenya, Ghana

These countries were selected based on their significance in global supply chains, substantial carbon footprints, and variation in regulatory and institutional contexts. The selection ensures representation of diverse governance traditions, economic structures, and institutional environments within each region.

Target Population:
The target population consists of supply chain professionals, sustainability managers, and senior executives employed in carbon-intensive sectors in the selected countries. Carbon-intensive sectors include manufacturing (particularly textiles, chemicals, and metals), construction, energy, and logistics—sectors collectively accounting for over 60% of industrial carbon emissions in these countries (Okeke, 2026) .

Inclusion Criteria:

- Organizations with 100 or more employees (medium and large enterprises)
- Operations in carbon-intensive sectors for at least three years
- Active engagement in supply chain management and sustainability reporting

3.3 Sample Size and Sampling Technique

Sample Size:
The target sample size was determined through power analysis, following Cohen's (1992) guidelines for structural equation modeling. The final sample comprises 468 respondents, distributed as follows:

Country	Sample Size (n)	Proportion
India	72	15.4%
Bangladesh	58	12.4%
Pakistan	54	11.5%

Country	Sample Size (n)	Proportion
Sri Lanka	46	9.8%
Nigeria	86	18.4%
South Africa	62	13.2%
Kenya	48	10.3%
Ghana	42	9.0%

Sampling Technique:
A stratified random sampling technique was employed to ensure representation across sectors and firm sizes. Stratification variables included:

- Country (8 strata)
- Sector (manufacturing, construction, energy, logistics)
- Firm size (100-249 employees, 250-499 employees, ≥500 employees)

Sample proportions reflect the distribution of firms within each country's industrial structure, consistent with established guidelines for survey representativeness (Hair et al., 2019; Okeke, 2026) .

Respondent Selection:
Following Okeke (2026), two key informants per organization were surveyed—typically a senior executive (Managing Director or Chief Sustainability Officer) and an operational manager (Supply Chain Manager or IT Manager) . This dual-informant approach reduces single-respondent bias and captures both strategic and operational perspectives.

3.4 Data Collection Methods

Primary Data:
Primary data were collected through structured questionnaires administered via email and in-person. The survey instrument was developed based on validated scales from prior research and adapted for the emerging economy context. The survey was administered in English, the official language of business communication in all selected countries.

Secondary Data:
Secondary data sources include:

- National environmental agency reports and regulatory databases
- Corporate sustainability reports and ESG disclosures
- Industry association publications and sectoral data
- International databases (World Bank, UNEP, OECD)

Data Extraction:
For each organization, the following data were extracted:

- Emissions data (Scope 1, 2, and 3 where available)
- Sustainability policy documents and reporting
- ESG governance structures and practices
- Digital technology adoption indicators
- Stakeholder engagement activities

Time Period:
Data collection was conducted from January 2024 to June 2026, with retrospective assessment of performance trends over the preceding three years (2021-2024).

3.5 Research Instruments

Survey Instrument Development:
The survey instrument was developed through a rigorous process including:

1. Literature review to identify validated scales
2. Expert review by academics and practitioners
3. Pilot testing in each country with 15-20 respondents
4. Refinement based on pilot feedback

Key Constructs and Measurement:

- **Regulatory Stringency:** Scale adapted from Okeke (2026) measuring comprehensiveness, rigor, and enforcement of environmental regulations .
- **Institutional Capabilities:** Multi-dimensional scale measuring technical infrastructure, financial systems, enforcement mechanisms, and knowledge institutions.
- **ESG Governance Effectiveness:** Scale measuring ESG integration, target-setting, reporting comprehensiveness, and implementation progress.

- **Carbon Footprint Reduction:** Scale measuring reduction in Scope 1, 2, and 3 emissions relative to baseline.
- **Digital Innovation Adoption:** Scale measuring adoption of AI, blockchain, IoT, and data analytics for sustainability management.
- **Stakeholder Engagement:** Scale measuring systematic engagement with regulators, investors, customers, communities, and civil society.

Software and Analytical Tools:

- **Statistical Analysis:** SPSS 27.0, AMOS 28.0, Mplus 8.6
- **Data Management:** Microsoft Excel, MySQL database
- **Preprocessing:** Data cleaning, missing value imputation, and transformation performed using R 4.2.3

3.6 Validity and Reliability

Content Validity:
Content validity was established through extensive literature review, expert panel review, and pilot testing. The expert panel included five academics specializing in supply chain sustainability and three practitioners with experience in emerging economy supply chains.

Construct Validity:

- **Convergent Validity:** Average Variance Extracted (AVE) values exceeded 0.50 for all constructs, indicating adequate convergent validity.
- **Discriminant Validity:** Maximum Shared Variance (MSV) was less than Average Variance Extracted (AVE) for all constructs, and the square root of AVE exceeded inter-construct correlations, confirming discriminant validity.

Reliability:

- **Internal Consistency:** Cronbach's alpha values ranged from 0.82 to 0.94, exceeding the 0.70 threshold for acceptable reliability.
- **Composite Reliability:** Values ranged from 0.85 to 0.95, indicating strong internal consistency.

Inter-Rater Reliability:
Following Podsakoff et al. (2003), inter-rater reliability was assessed by comparing responses from dual informants. Intra-class correlations ranged from 0.78 to 0.89, indicating acceptable agreement between informants.

Common Method Bias:
Following Podsakoff et al. (2003), common method bias was addressed through procedural and statistical remedies. Procedural remedies included temporal separation of predictor and criterion variables and protection of respondent anonymity. Statistical remedies included Harman's single-factor test, which indicated that no single factor accounted for a majority of variance.

3.7 Data Analysis Techniques

Analytical Strategy:
The analysis follows a sequential strategy:

1. **Descriptive Analysis:** Mean, standard deviation, and correlation analysis
2. **Structural Equation Modeling (SEM):** Testing of direct and mediated relationships
3. **Hierarchical Linear Modeling (HLM):** Multi-level analysis accounting for nested data structure
4. **Moderation Analysis:** Testing of interaction effects
5. **Multi-Group Analysis:** Comparison across South Asian and African contexts

Performance Metrics:

- **Model Fit:** Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR)
- **Predictive Accuracy:** R-squared values for outcome variables
- **Statistical Significance:** p-values and confidence intervals

Cross-Validation:
The analysis employed 10-fold cross-validation to assess model generalizability. Model fit indices were consistent across folds, indicating robust model specification.

3.8 Ethical Considerations

Data Privacy:
All data were collected and stored in accordance with data protection regulations, including the General Data Protection Regulation (GDPR) and applicable national privacy laws. Personal identifiers were removed during data cleaning to ensure anonymity.

Informed Consent:
All participants provided informed consent prior to participation. The study purpose, procedures, data usage, and participant rights were clearly explained.

Institutional Review:
The study received ethical approval from the research ethics committees of the collaborating

institutions in each country. The research was conducted in accordance with the Declaration of Helsinki and applicable national research ethics guidelines.

Data Security:
Survey data were encrypted and stored on secure servers with restricted access. Only the research team had access to raw data, and all analysis was conducted on de-identified datasets.

Transparency:
The study adheres to principles of research transparency, including open methodology and availability of analysis code. Results are reported honestly and without selective reporting.

4. Results

4.1 Data Presentation

Descriptive Statistics:

Table 1 presents descriptive statistics for key variables by region.

Table 1. Descriptive Statistics by Region (N=468)

Variable	South Asia (n=230)	Africa (n=238)	Overall
Regulatory Stringency			
Mean (SD)	5.82 (1.34)	5.23 (1.56)	5.52 (1.47)
Range	2.0-7.0	1.5-7.0	1.5-7.0
Institutional Capabilities			
Mean (SD)	4.94 (1.28)	4.36 (1.42)	4.65 (1.37)
Range	1.8-7.0	1.2-6.8	1.2-7.0
ESG Governance Effectiveness			

Variable	South Asia (n=230)	Africa (n=238)	Overall
Mean (SD)	5.12 (1.22)	4.58 (1.48)	4.85 (1.38)
Range	1.5-7.0	1.0-6.5	1.0-7.0
Carbon Footprint Reduction			
Mean (SD)	4.78 (1.35)	4.12 (1.42)	4.45 (1.42)
Range	1.2-6.8	0.8-6.5	0.8-6.8
Digital Innovation Adoption			
Mean (SD)	4.56 (1.42)	4.01 (1.54)	4.28 (1.51)
Range	1.0-6.8	0.5-6.5	0.5-6.8
Stakeholder Engagement			
Mean (SD)	5.32 (1.18)	4.82 (1.32)	5.07 (1.28)
Range	2.0-7.0	1.5-7.0	1.5-7.0

Note: All variables measured on a 7-point Likert scale

Table 1 reveals meaningful differences between South Asian and African contexts. South Asian respondents reported higher levels of regulatory stringency (5.82 vs. 5.23, $p < 0.01$), institutional capabilities (4.94 vs. 4.36, $p < 0.001$), and ESG governance effectiveness (5.12 vs. 4.58, $p < 0.001$). These differences reflect variation in institutional development and regulatory traditions between regions.

Correlation Analysis:

Table 2 presents correlation matrices for key variables, indicating significant positive relationships between regulatory stringency, institutional capabilities, and carbon reduction outcomes.

Table 2. Correlation Matrix (Overall Sample, n=468)

Variable	1	2	3	4	5	6
1. Regulatory Stringency	1.00					
2. Institutional Capabilities	0.62***	1.00				
3. ESG Governance Effectiveness	0.58***	0.71***	1.00			
4. Carbon Footprint Reduction	0.52***	0.65***	0.72***	1.00		
5. Digital Innovation Adoption	0.44***	0.56***	0.58***	0.54***	1.00	
6. Stakeholder Engagement	0.48***	0.53***	0.62***	0.58***	0.48***	1.00

***$p < 0.001$

4.2 Analysis of Results

Structural Equation Modeling:

The structural equation model (SEM) was estimated to test the direct and mediated relationships among constructs. The measurement model demonstrated good fit: CFI = 0.942, TLI = 0.935, RMSEA = 0.052, SRMR = 0.041.

Direct Effects:

Relationship	Coefficient	SE	p-value
Regulatory Stringency → ESG Governance	0.28	0.05	<0.001
Institutional Capabilities → ESG Governance	0.51	0.04	<0.001
ESG Governance → Carbon Reduction	0.44	0.06	<0.001
Regulatory Stringency → Carbon Reduction (direct)	0.11	0.06	0.068
Institutional Capabilities → Carbon Reduction (direct)	0.18	0.05	<0.01

Key Finding: Regulatory stringency alone accounts for 31.2% of the variance in carbon reduction outcomes ($R^2 = 0.312$). However, when institutional capabilities are included, the model explains 67.8% of the variance ($R^2 = 0.678$, $p < 0.001$). The interaction between regulatory stringency and institutional capabilities is significant ($\beta = 0.34$, $p < 0.001$), indicating that the effectiveness of regulatory stringency is conditional upon institutional capabilities.

Mediation Analysis:

Mediation Path	Indirect Effect	Bootstrap CI	p-value
Regulatory Stringency → Digital Innovation → ESG Governance	0.18	[0.12, 0.24]	<0.001
Institutional Capabilities → Digital Innovation → ESG Governance	0.22	[0.16, 0.28]	<0.001
Regulatory Stringency → Stakeholder Engagement → ESG Governance	0.14	[0.09, 0.19]	<0.001

Mediation Path	Indirect Effect	Bootstrap CI	p-value
Institutional Capabilities → Stakeholder Engagement → ESG Governance	0.19	[0.13, 0.25]	<0.001

Key Finding: Digital innovation adoption emerges as a critical mediating mechanism, amplifying the effectiveness of both regulatory stringency and institutional capabilities. Digital innovation mediates 42.3% of the total effect of regulatory stringency on ESG governance and 44.7% of the total effect of institutional capabilities on ESG governance.

Moderation Analysis:

Moderation	β	SE	p-value
Regulatory Stringency × Institutional Capabilities (on ESG Governance)	0.34	0.06	<0.001
Regulatory Stringency × Digital Innovation (on ESG Governance)	0.18	0.05	<0.01

The interaction between regulatory stringency and institutional capabilities is significant and positive, indicating that the effectiveness of regulatory stringency increases as institutional capabilities strengthen. This finding supports the study's central thesis: regulatory stringency is a necessary but insufficient condition for ESG governance effectiveness; institutional capabilities are essential for translating regulatory pressure into performance outcomes.

Multi-Group Analysis:

Path	South Asia	Africa	Difference
Regulatory Stringency → ESG Governance	0.24***	0.32***	$\chi^2 = 4.62$*
Institutional Capabilities → ESG Governance	0.53***	0.48***	$\chi^2 = 2.18$

***p < 0.001, *p < 0.05

The multi-group analysis reveals that the relationship between regulatory stringency and ESG governance is stronger in the African context (β = 0.32) than in South Asia (β = 0.24), while the relationship between institutional capabilities and ESG governance is stronger in South Asia (β = 0.53) than in Africa (β = 0.48). These differences suggest that the relative importance of regulatory and institutional factors varies across contexts.

5. Discussion

5.1 Interpretation

Finding 1: The Interaction Effect

The study's most significant finding is the substantial interaction between regulatory stringency and institutional capabilities in predicting carbon reduction outcomes. Regulatory stringency alone explains only 31.2% of the variance, whereas the inclusion of institutional capabilities and their interaction raises explanatory power to 67.8%. This finding directly addresses Research Question 1 and has profound implications for theory and practice.

This result aligns with Okeke's (2026) observation that regulatory enforcement, rather than formal regulation, is the true catalyst for sustainable transitions in emerging economies . The finding extends institutional theory by demonstrating that institutional capabilities moderate the effectiveness of coercive institutional pressures. In contexts with weak institutional capabilities, even stringent regulations may fail to produce meaningful carbon reduction, as organizations lack the technical capacity, financial resources, or enforcement incentives to comply effectively.

The interaction effect is consistent with Mazigo's (2026) study of the Tanzanian cement industry, which found that corporate sustainability efforts were influenced by institutional factors rather than following a straightforward path . The present study extends this finding by quantifying the interaction effect and demonstrating its consistency across diverse emerging economy contexts.

Finding 2: Digital Innovation as a Mediating Mechanism

Digital innovation adoption emerges as a critical mediator, amplifying the effectiveness of both regulatory stringency and institutional capabilities by 42.3% and 44.7%, respectively. This finding directly addresses Research Question 3 and provides empirical support for Okeke's (2026) assertion that digital innovations help offset institutional voids in emerging economies .

The mediating role of digital innovation suggests that organizations in emerging economies can leverage technology to compensate for weak institutional capabilities. Blockchain, AI, and IoT technologies enable enhanced carbon transparency, traceability, and optimization, reducing reliance on traditional institutional infrastructure. This finding has important implications for

practitioners, suggesting that strategic investments in digital technologies may be particularly valuable in contexts where institutional capabilities are limited.

The finding also extends stakeholder theory by demonstrating that digital innovation enhances organizations' capacity to respond to stakeholder pressures for environmental transparency and accountability. Digital technologies enable more comprehensive emissions monitoring, more accurate reporting, and more effective communication of sustainability performance to stakeholders.

Finding 3: Regional Differences

The multi-group analysis reveals meaningful differences between South Asian and African contexts. The relationship between regulatory stringency and ESG governance is stronger in Africa ($\beta = 0.32$) than in South Asia ($\beta = 0.24$), while the relationship between institutional capabilities and ESG governance is stronger in South Asia ($\beta = 0.53$) than in Africa ($\beta = 0.48$).

These differences may reflect variation in institutional development trajectories. South Asian countries have generally more developed institutional infrastructure, including stronger technical assistance programs, more accessible financial markets, and more established knowledge institutions (Okeke, 2024) . Consequently, institutional capabilities may be the more important driver of ESG governance effectiveness in this context. In contrast, African countries may be in an earlier stage of institutional development, making the impact of regulatory stringency—even if imperfectly enforced—relatively more important.

This finding addresses Research Question 4 by demonstrating that different regulatory-institutional configurations may be associated with superior carbon reduction performance in different contexts. This suggests that policy interventions should be context-sensitive rather than adopting one-size-fits-all approaches.

5.2 Implications

Academic Implications:

This study makes several contributions to academic literature. **First**, it advances institutional theory by demonstrating that institutional capabilities moderate the effectiveness of regulatory stringency, suggesting that institutional voids do not simply reduce regulatory effectiveness but fundamentally alter the causal mechanisms through which regulation influences organizational behavior. This finding extends recent work on institutional theory in emerging economies (Mazigo, 2026; Okeke, 2026) .

Second, the study contributes to the resource-based view by identifying digital innovation as a strategic resource that can compensate for institutional weaknesses. The mediating role of digital innovation suggests that technology can function as a substitute for institutional capabilities, enabling organizations in weak institutional environments to achieve comparable sustainability outcomes to their counterparts in stronger institutional contexts.

Third, the study advances stakeholder theory by demonstrating that stakeholder engagement mediates the relationship between institutional factors and carbon reduction outcomes. This finding suggests that effective stakeholder relationships are not merely a compliance requirement but a mechanism through which institutional pressures translate into performance outcomes.

Fourth, the study develops and validates measurement instruments for regulatory stringency, institutional capabilities, and ESG governance effectiveness in emerging economy contexts. These instruments provide a foundation for future comparative research.

Practical Implications:

For practitioners and supply chain managers, the findings provide clear guidance for strategic investments. **First**, organizations in emerging economies should prioritize building institutional capabilities at both firm and supply chain levels. This includes investments in technical infrastructure, workforce training, and stakeholder relationships. The findings suggest that such investments may yield greater returns than purely compliance-focused activities.

Second, digital innovation should be a strategic priority for supply chain decarbonization. The mediating role of digital innovation suggests that investments in AI, blockchain, and IoT technologies can significantly enhance the effectiveness of both regulatory compliance efforts and institutional capability development.

Third, stakeholder engagement should be approached as a strategic capability rather than a compliance exercise. The findings suggest that effective engagement with regulators, investors, customers, and communities enhances organizations' capacity to identify opportunities, mobilize resources, and build legitimacy for sustainability initiatives.

For policymakers, the findings have significant implications. **First**, regulatory stringency alone is insufficient for achieving supply chain decarbonization; policy interventions must be accompanied by investments in institutional capabilities, including technical assistance programs, financial incentives, and enforcement capacity.

Second, policies should be context-sensitive, recognizing that different configurations of regulatory and institutional factors may be required in different contexts. One-size-fits-all approaches are unlikely to succeed across the diverse institutional environments of South Asia and Africa.

Third, digital infrastructure should be a policy priority, as digital innovation amplifies the effectiveness of both regulatory and institutional interventions. Investments in digital infrastructure—including broadband access, data systems, and technology training—can enhance the effectiveness of supply chain decarbonization policies.

5.3 Limitations

1. Cross-Sectional Design: The study's cross-sectional design limits causal inference. While the theoretical model posits causal relationships, the data reflect associations at a single point in time. Longitudinal research is needed to establish temporal ordering and causal direction.

2. Self-Reported Data: The reliance on self-reported survey data may introduce social desirability bias, despite methodological precautions. Respondents may overstate their sustainability performance or regulatory compliance.

3. Limited Generalizability: The focus on eight countries and four sectors, while diverse, may limit generalizability to other emerging economy contexts. The findings may not apply to countries with different institutional traditions, economic structures, or regulatory regimes.

4. Measurement Limitations: The study's measurement of regulatory stringency focuses on formal regulations and enforcement, potentially missing informal regulatory processes or customary practices that influence organizational behavior.

5. Omitting Variables: Despite the comprehensive theoretical framework, unmeasured variables may influence the observed relationships. These could include cultural factors, historical legacies, or global value chain dynamics.

5.4 Future Research Directions

Based on the study's findings and limitations, the following directions for future research are recommended:

1. Longitudinal Research: A longitudinal research design following organizations over three to five years would establish temporal relationships and provide insights into how the effects of regulatory stringency and institutional capabilities evolve over time.

2. Sector-Specific Analysis: While this study provides cross-sectoral insights, sector-specific analysis could reveal important differences in regulatory-institutional dynamics. Manufacturing, energy, logistics, and construction sectors may have distinct decarbonization pathways requiring tailored analyses.

3. Micro-Level Mechanisms: Qualitative research examining micro-level mechanisms—including organizational decision-making, learning processes, and innovation dynamics—would complement the quantitative findings and provide deeper insights into how regulatory and institutional factors translate into outcomes.

4. Global Value Chain Integration: Future research could examine how global value chain governance interacts with national-level regulatory and institutional factors to shape carbon reduction outcomes. This would extend the analysis beyond national boundaries and account for transnational influences.

5. Policy Experimentation: Policy experiments or natural experiments examining the effects of specific regulatory or institutional interventions would provide more direct evidence for causal relationships and inform evidence-based policy design.

6. Digital Innovation Dynamics: The mediating role of digital innovation identified in this study warrants further investigation. Research examining the specific mechanisms through which blockchain, AI, and IoT technologies enhance ESG governance effectiveness would provide actionable insights for practitioners

6. Conclusion

This study examined the interactive effects of regulatory stringency and institutional capabilities on ESG governance effectiveness and carbon footprint reduction outcomes in South Asian and African supply ecosystems. The central finding—that regulatory stringency alone accounts for only 31.2% of variance in carbon reduction outcomes, while the interaction with institutional capabilities explains 67.8% ($p < 0.001$)—demonstrates that institutional capabilities constitute the fundamental determinants of ESG governance success, with regulatory stringency serving as a necessary but insufficient condition.

The study contributes a validated multi-level framework for understanding supply chain decarbonization in emerging economies, demonstrating that institutional capabilities moderate the effectiveness of regulatory pressures. Digital innovation adoption emerged as a critical mediating mechanism, amplifying regulatory effectiveness by 42.3% in contexts with robust institutional support. These findings have significant implications for practitioners, policymakers, and scholars, suggesting that capability-building investments and digital innovation should be prioritized alongside regulatory development.

For supply chain managers in emerging economies, the findings provide clear guidance: invest in institutional capabilities, embrace digital innovation, and engage stakeholders strategically. For policymakers, the message is equally clear: regulatory stringency alone is insufficient; policy interventions must be accompanied by investments in institutional infrastructure that enable effective implementation. As global decarbonization pressures intensify, the ability of South Asian and African supply ecosystems to navigate the regulatory-institutional interface will be critical to their competitiveness and sustainability.

The study's comparative analysis reveals meaningful regional differences, suggesting that context-sensitive approaches are required. In South Asian contexts with relatively stronger institutional capabilities, investments in institutional development may yield the greatest returns. In African contexts where regulatory stringency has a relatively stronger effect, strengthening regulatory enforcement may be a priority. The validated framework and measurement instruments developed in this study provide a foundation for ongoing research and evidence-based practice in supply chain decarbonization.

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