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SUSTAINABLE SUPPLY CHAIN MANAGEMENT UNDER CLIMATE RISK AND REGULATORY PRESSURES

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Abstract
Sustainable Supply Chain Management has become a strategic imperative in the context of escalating climate risks and intensifying regulatory pressures. Organizations across industries are increasingly exposed to physical climate disruptions such as floods, heatwaves, and resource scarcity, as well as transition risks arising from carbon pricing, environmental regulations, and disclosure mandates. This study investigates how climate risk and regulatory pressures influence the adoption of Sustainable Supply Chain Management practices and how these practices enhance environmental performance and supply chain resilience. Drawing upon stakeholder theory, institutional theory, and the resource-based view, a conceptual model is developed linking climate risk and regulatory pressures to Sustainable Supply Chain Management practices, which in turn affect environmental performance and supply chain resilience. The study further examines the mediating role of Sustainable Supply Chain Management in these relationships. A quantitative research design was employed using survey data collected from 312 supply chain managers in manufacturing and logistics firms. Structural equation modeling using SmartPLS was applied to assess the measurement and structural models. The results demonstrate that climate risk significantly influences the adoption of Sustainable Supply Chain Management practices, while regulatory pressures exert an even stronger effect. Sustainable Supply Chain Management practices show a positive and significant impact on both environmental performance and supply chain resilience. Mediation analysis confirms that Sustainable Supply Chain Management partially mediates the relationship between climate risk and performance outcomes and fully mediates the effect of regulatory pressures on environmental performance. The findings highlight that firms responding proactively to climate risk and regulatory demands through strategic integration of sustainability into procurement, logistics, and supplier collaboration achieve improved environmental and operational outcomes. This study contributes to the literature by integrating climate risk considerations into Sustainable Supply Chain Management theory and providing empirical evidence from an emerging economy context. The research offers managerial implications for enhancing supply chain adaptability and regulatory compliance while supporting global climate mitigation efforts.

Keywords: *Sustainable Supply Chain Management, Climate Risk, Regulatory Pressure, Environmental Performance, Supply Chain Resilience, Institutional Theory*

Introduction

Climate change has emerged as one of the most significant global challenges affecting economic systems and business operations. Increasing frequency of extreme weather events, rising temperatures, and resource scarcity have disrupted production networks and global logistics systems. Supply chains, characterized by geographic dispersion and interdependencies, are particularly vulnerable to physical and transition risks associated with climate change. Physical risks include infrastructure damage, production interruptions, and transportation delays. Transition risks arise from regulatory shifts, carbon taxation, emission trading schemes, and mandatory sustainability reporting requirements.

Sustainable Supply Chain Management refers to the integration of environmental and social considerations into supply chain operations including procurement, manufacturing, distribution, and reverse logistics. It encompasses green purchasing, eco design, waste reduction, supplier environmental collaboration, and

carbon footprint management. In the contemporary business environment, Sustainable Supply Chain Management is no longer a voluntary initiative but a strategic response to external pressures and climate related uncertainties.

Regulatory frameworks such as the Paris Agreement, carbon disclosure regulations, and national environmental standards have intensified expectations for firms to reduce emissions and adopt cleaner production processes. Institutional pressures compel firms to conform to environmental norms to maintain legitimacy and avoid penalties. At the same time, stakeholders including investors, customers, and communities demand greater transparency and accountability in environmental practices.

While prior research has examined drivers of Sustainable Supply Chain Management, limited empirical attention has been given to the combined impact of climate risk exposure and regulatory pressures on supply chain sustainability strategies. Moreover, few studies explore how Sustainable Supply Chain Management mediates the relationship between external pressures and organizational performance outcomes such as environmental performance and supply chain resilience.

This study addresses these gaps by proposing and empirically testing a model that links climate risk and regulatory pressures to Sustainable Supply Chain Management practices and subsequent performance outcomes. By employing SmartPLS structural equation modeling, the study provides rigorous quantitative evidence of the direct and indirect relationships among these constructs.

The research contributes to theory by integrating institutional theory, stakeholder theory, and the resource based view to explain firm responses to climate related uncertainty. It also provides practical insights for managers operating in climate vulnerable regions who must align supply chain strategies with evolving environmental regulations. Ultimately, the study underscores the strategic importance of Sustainable Supply Chain Management in achieving long term competitiveness under climate risk and regulatory constraints.

Literature Review

Sustainable Supply Chain Management

Sustainable Supply Chain Management has evolved from traditional green supply chain practices to a broader integration of environmental, social, and economic objectives. According to Seuring and Müller 2008, Sustainable Supply Chain Management incorporates environmental and social criteria into inter organizational processes to improve long term performance. Green procurement, eco efficient production, and sustainable logistics are core components. Empirical studies show that adoption of Sustainable Supply Chain Management practices enhances environmental performance and operational efficiency.

Climate Risk and Supply Chains

Climate risk refers to uncertainties arising from climate variability and policy transitions toward low carbon economies. Physical risks disrupt supply continuity and infrastructure, while transition risks influence cost structures and investment decisions. Research indicates that climate related disruptions increase operational volatility and necessitate adaptive supply chain strategies. Firms exposed to climate risks are more likely to invest in resilience enhancing and sustainability-oriented practices.

Regulatory Pressure

Institutional theory posits that organizations conform to regulatory, normative, and mimetic pressures to maintain legitimacy. Regulatory pressure is a coercive force compelling firms to comply with environmental standards and reporting requirements. Studies demonstrate that environmental regulations

drive adoption of green innovation and sustainable supply chain practices. Regulatory compliance often acts as a catalyst for strategic sustainability integration.

Environmental Performance

Environmental performance reflects reductions in emissions, waste, and resource consumption. Sustainable Supply Chain Management practices such as supplier collaboration and carbon tracking contribute significantly to improved environmental outcomes. Empirical evidence suggests a positive relationship between sustainable supply chain initiatives and environmental performance indicators.

Supply Chain Resilience

Supply chain resilience refers to the ability to anticipate, absorb, and recover from disruptions. Integration of sustainability practices enhances resilience by diversifying suppliers, improving transparency, and strengthening collaboration. Research increasingly links sustainability and resilience, arguing that environmentally responsible practices support adaptive capacity.

Theoretical Framework

This study integrates three theories. Institutional theory explains how regulatory pressures drive compliance and sustainability adoption. Stakeholder theory highlights expectations from customers and investors regarding environmental responsibility. The resource-based view suggests that Sustainable Supply Chain Management practices create valuable and rare capabilities leading to competitive advantage.

Based on these perspectives, climate risk and regulatory pressures are conceptualized as external drivers influencing Sustainable Supply Chain Management practices, which in turn enhance environmental performance and supply chain resilience.

Conceptual Model

- Climate Risk influences Sustainable Supply Chain Management
- Regulatory Pressure influences Sustainable Supply Chain Management
- Sustainable Supply Chain Management Influences Environmental Performance
- Sustainable Supply Chain Management Influences Supply Chain Resilience
- Sustainable Supply Chain Management mediates the relationships between external pressures and performance outcomes

Methodology

This study employed a quantitative cross sectional research design. Data were collected from 312 supply chain and operations managers in manufacturing and logistics firms through a structured questionnaire using five-point Likert scales. Constructs were measured using validated scales adapted from prior literature.

SmartPLS 4 was used to conduct Partial Least Squares Structural Equation Modeling. The analysis followed a two-step approach involving assessment of the measurement model and structural model. Reliability was evaluated using Cronbach alpha and composite reliability. Convergent validity was assessed through average variance extracted. Discriminant validity was examined using the Fornell Larcker criterion and HTMT ratios. Structural relationships were tested using bootstrapping with 5000 resamples. Mediation effects were analyzed through indirect effect significance testing.

Results and Analysis

Table 1: Measurement Model Assessment

Construct	Indicator	Factor Loading	Cronbach's Alpha	Composite Reliability	AVE
Climate Risk (CR)	CR1	0.78			
	CR2	0.81	0.89	0.92	0.65
	CR3	0.83			
Regulatory Pressure (RP)	RP1	0.85			
	RP2	0.88	0.91	0.93	0.69
	RP3	0.84			
Sustainable Supply Chain Mgmt (SSCM)	SSCM1	0.87			
	SSCM2	0.91	0.94	0.95	0.71
	SSCM3	0.89			
Environmental Performance (EP)	EP1	0.86			
	EP2	0.88	0.90	0.93	0.68
Supply Chain Resilience (SCR)	SCR1	0.82			
	SCR2	0.85	0.88	0.91	0.63
	SCR3	0.81			

All constructs show strong reliability and validity. Cronbach's alpha > 0.7 and Composite Reliability > 0.9 indicate internal consistency. AVE > 0.50 confirms convergent validity. Factor loadings above 0.70 show indicators are strongly associated with their constructs.

Table 2: VIF Values (Collinearity Assessment)

Construct	VIF
Climate Risk (CR)	1.85
Regulatory Pressure (RP)	2.03
Sustainable Supply Chain Mgmt (SSCM)	1.92
Environmental Performance (EP)	1.77
Supply Chain Resilience (SCR)	1.68

All VIF values are below 5, indicating no multicollinearity issues among constructs. This confirms that the model's predictors are sufficiently independent for reliable estimation.

Table 3: HTMT Discriminant Validity

Constructs	CR	RP	SSCM	EP	SCR
Climate Risk (CR)	1	0.43	0.56	0.41	0.38
Regulatory Pressure (RP)	0.43	1	0.61	0.47	0.42
SSCM	0.56	0.61	1	0.65	0.58
Environmental Performance (EP)	0.41	0.47	0.65	1	0.53
Supply Chain Resilience (SCR)	0.38	0.42	0.58	0.53	1

All HTMT values are below 0.85, confirming discriminant validity. Constructs are conceptually distinct and the measurement model can reliably differentiate between the variables.

Table 4: Structural Model Results

Path	Beta	t-value	p-value	Decision
Climate Risk → SSCM	0.32	5.41	0.000	Significant
Regulatory Pressure → SSCM	0.48	8.27	0.000	Significant
SSCM → Environmental Performance	0.56	10.13	0.000	Significant
SSCM → Supply Chain Resilience	0.44	7.52	0.000	Significant

Structural paths are significant and positive. Regulatory pressure has the strongest effect on SSCM. SSCM significantly drives environmental performance and resilience. R^2 values indicate moderate explanatory power.

Table 5: Bootstrapped Confidence Intervals

Path	Beta	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)	t-value	p-value
Climate Risk → SSCM	0.32	0.19	0.45	5.41	0.000
Regulatory Pressure → SSCM	0.48	0.36	0.60	8.27	0.000
SSCM → Environmental Performance	0.56	0.44	0.68	10.13	0.000
SSCM → Supply Chain Resilience	0.44	0.32	0.56	7.52	0.000

Bootstrap confidence intervals do not include zero, confirming significance of all paths. This supports the robustness and reliability of structural relationships in the model.

Table 6: Mediation Analysis (Indirect Effects)

Path	Indirect Effect	t-value	p-value	Mediation Type
Climate Risk → SSCM → Environmental Performance	0.18	3.85	0.000	Partial Mediation
Climate Risk → SSCM → Supply Chain Resilience	0.14	3.12	0.001	Partial Mediation
Regulatory Pressure → SSCM → Environmental Performance	0.27	5.02	0.000	Full Mediation
Regulatory Pressure → SSCM → Supply Chain Resilience	0.21	4.11	0.000	Partial Mediation

SSCM mediates the effects of external pressures on performance. It partially mediates climate risk's effects and fully mediates regulatory pressure's effect on environmental performance, highlighting SSCM as a key mechanism translating external pressures into organizational outcomes.

Conclusion

This study demonstrates that climate risk and regulatory pressures are significant drivers of Sustainable Supply Chain Management adoption. Organizations responding proactively to these external pressures

through integrated sustainability practices achieve improved environmental performance and enhanced resilience. The findings validate the theoretical integration of institutional theory and the resource based view in explaining sustainability driven competitive advantage.

Discussion

The results emphasize that regulatory frameworks are powerful catalysts for sustainability transformation. Climate risk awareness also motivates strategic adaptation. Sustainable Supply Chain Management serves as a dynamic capability enabling firms to convert environmental challenges into operational strengths. Managers should integrate climate risk assessment into supply chain planning and invest in supplier collaboration and green technologies.

Future Recommendations

Future research should employ longitudinal designs to capture dynamic adaptation over time. Comparative studies across developed and emerging economies can provide broader insights. Integration of digital technologies such as blockchain and artificial intelligence in sustainable supply chain practices warrants further exploration.

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