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KEYWORDS	ABSTRACT
Sustainable Supply Chain Management, Environmental Sustainability, Environmental Regulatory Quality, Developing Countries, Panel Data	Environmental sustainability has become major challenge for developing countries due to rapid industrialization, increasing resource consumption, and environmental degradation. This study examines impact of sustainable supply chain management on environment sustainability, with moderating variable: environmental regulatory quality. The data were obtained from internationally recognized sources, including World Bank, WGI, EPI, OECD & United Nations databases. Thus, panel regression techniques, including descriptive statistics, correlation analysis, fixed and random effects models, Hausman test, moderation analysis, and robustness checks, were used for the data analysis. Findings reveal that SSCM has a positive and statistically significant effect on environmental sustainability. The ERQ also positively influences environmental sustainability and significantly strengthens the relationship between SSCM and environmental sustainability. These results indicate that effective regulatory frameworks enhance the environmental benefits of the sustainable supply chain practices. The study concludes that improving environmental sustainability measures in developing countries requires the combined efforts of organizations adopting sustainable supply chain leading practices and measures from governments for strengthening environmental governance.
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INTRODUCTION

The sustainable Supply Chain Management (SSCM) is a strategy that has been increasingly turning attention to environmental issues of globalization, industrialization & climate change. With growing awareness of environmental degradation, resource depletion, and greenhouse gas issues, entities are turning to the concept of sustainable supply chain (Abdul & Ibrahim, 2025). The growing concern

about environmental degradation, resource depletion, and GHGs has led organizations to consider practices that involve a supply chain that balances economic performance with the environmental protection and social responsibility. As opposed to the traditional supply chain management, which mainly focused on cost reduction and operational efficiency, SSCM takes environmental and social aspects into consideration in procurement, production, transportation, and distribution. Sustainable initiatives along the entire supply chain help organizations to lower their environmental impact and enhance their long-term competitiveness and resilience (Mohsin, Schmidt, Aschauer, Plasch & Gerschberger, 2025). Environmental sustainability is one of underlying goals of sustainable supply chain management as it involves using natural resources responsibly as well as reducing negative impacts on environment.

The sustainable supply chain practices that reduce carbon emissions, develop the energy efficiency, minimize waste creation and inspire recycling and the circular economy make a major contribution towards protecting the environment. Such activities also contribute to global sustainability efforts, such as united nations sustainable development goals, fostering sustainable production as well as consumption patterns. Thus, a robust integration of sustainability in the operations of supply chains not only accounts for environmental considerations but also enhances the market advantage and stakeholder trust (Ali, Majeed, Latif & Aldrickzler, 2024; Mohsin, Schmidt, Aschauer, Plasch & Gerschberger, 2025). The successful implementation of sustainable supply chain practices depends on the environmental regulatory quality. A key feature of effective environmental regulation is to set standards that can incentivize organizations to cut pollution, waste in resource use, to use cleaner production technologies and to meet the environmental laws. Enabling regulations also encourage innovation by incentivizing the companies to invest in environmentally sustainable technologies and business models.

The weak regulatory systems can have a negative impact on SSCM which can hinder environmental performance and the rate of progress towards sustainability goals. Thus, the positive or negative link between SSCM and environmental sustainability can be reinforced or undermined by quality of environment regulation (Kato & Manchidi, 2025; Štreimikienė, Bathaei & Streimikis, 2024). The present study investigates the role of SSCM on environmental sustainability in some selected developing countries amid 2015 and 2025. Besides, it examines moderating effect of environmental regulatory quality in relation between these two, based on the secondary panel data. This research builds on existing research by including empirical evidence on sustainable supply chain practices and their performance impact based on institutional quality for developing countries. The results should have practical implications for policy makers, business managers and researchers concerned about the sustainable development as well as environmental governance in the emerging economies (Bratt, Sroufe & Broman, 2021; Kumar, A., Shrivastav, Shrivastava, Mardani & Cavallaro, 2023; Mohsin et al., 2025).

So, there is a need for in-depth empirical evidence that investigates the relationship of sustainable supply chain management and environmental sustainability in the developing countries and if the quality of environmental regulation enhances or diminishes the relationship. The present study uses panel data for 10 developing countries for the period 2015-2025 to fill this void. This research aims

to further clarify the moderating effect of environmental regulatory quality on the impact of SSCM on environmental sustainability. The integration of sustainable supply chain practices with high-quality regulatory framework offers inclusive pathway to the environmentally responsible business operations, long-term ecological protection, efficient resource utilization, and sustainable economic development. These practices are intended to reduce ecological footprint generated throughout value chain. The results will balance existing literature and inform policy dialogue on sustainable development in developing economies, both by policy makers and business organizations as well as environmental regulators.

Research Objectives

To examine the impact of sustainable supply chain management on environmental sustainability. To investigate the effect of environmental regulatory quality on environmental sustainability. To examine moderating role of environmental regulatory quality between SSCM and environmental sustainability. Here are research questions: Does SSCM improve environmental sustainability? Does environmental regulatory quality influence the environmental sustainability? Does environmental regulatory quality strengthen relationship between SSCM and environmental sustainability? The hypotheses are: H1: sustainable supply chain management affects environmental sustainability. H2: the environmental regulatory quality positively affects the environmental sustainability. H3: and environmental regulatory quality positively moderates the relationship between SSCM as well as environmental sustainability.

Significance of Study

The importance of this study is that it is contributing to the ever-expanding body of knowledge relating to sustainable supply chain management, its contribution to environmental sustainability in developing countries. The study's results have contributed to empirical evidence of moderating effect of institutional factors on the effectiveness of sustainable supply chain practices. The results would be useful to a broad spectrum of the stakeholders, from policy makers and governments, to supply chain managers, environmental management agencies, and developing countries aiming for sustainable development.

LITERATURE REVIEW

Sustainable Supply Chain Management

The sustainable supply chain management is significant strategic approach that ensures long-term sustainability in the supply chain by incorporating environmental, social and economic aspects into the activities of chain in an integrated manner to achieve sustainability while keeping organization competitive. With regard to the focus of supply chain management, while traditional supply chain management is mainly for reducing cost and improving operational efficiency, SSCM emphasizes importance of balancing economic growth with environmental protection and social responsibility in the whole supply chain, from raw material procurement to production, distribution, consumption and product end-of-life management. The recent advancements have further bolstered SSCM by incorporating cutting-edge technologies like blockchain, Internet of Things, artificial intelligence, and big data analytics, which facilitate the transparency, traceability, collaboration, and decision-

making within supply chain networks (Ali et al., 2024; Mohsin et al., 2025; Younis, Bwaliez, Okaily & Tanveer, 2024).

Environmental Regulatory Quality

Environmental Regulatory Quality (ERQ) is the ability of environmental laws, policies, regulations and institutional mechanisms to achieve environmental protection and sustainable development. It demonstrates how well environmental laws are designed, enforced and carried out in a fair way to reach environmental goals that promote economic development. Good environmental regulation quality consists of clear legislation, effective governance, transparency of decision making, good institutional capacity & accountability in regulatory process (List & Gerking, 2000; Purdy, 2009). The indicators of the quality of environmental regulation are typically linked to the stringency of environmental laws, the ability of the government to effectively regulate, the quality of institutions, compliance rates, efficiency of enforcement, and rule of law. Moreover, governance indicators like policy coherence, inter-agency coordination, transparency & application of modern environmental monitoring technologies likewise satellite-based Earth observation systems and digital compliance tools are being used to measure the performance of regulations (Mokhtar et al., 2026; Zahid, Zhang, Gao & Oláh, 2025).

Theoretical Foundation

This study is based upon three complementary theories that explain the link between sustainable supply chain management & environmental sustainability, namely stakeholder theory, institutional theory and the resource-based view. The stakeholder theory states that the role of the organization is not just to satisfy shareholders but to satisfy the various stakeholders like customers, suppliers, governments, local communities, employees and environmental groups. In the framework of SSCM, stakeholder pressure that helps firms to embrace green procurement, sustainable sourcing, waste minimization and production processes that are green to achieve better environmental performance to continue to earn legitimacy (Li, Li, Li & Xu, 2025; Siems, Seuring & Schilling, 2022). As a result, organizations adopt sustainable supply chain management practices to boost performance but also to fulfill the regulatory requirements, gain legitimacy as well as meet the expectations of society to protect the environment (Peters, Hofstetter & Hoffmann, 2011; Garaihy, Farag, Shehri, Centobelli & Cerchione, 2022).

Moderating Role of Environmental Regulatory Quality

The environmental regulatory quality has a strong moderating effect on the relationship between sustainable supply chain management and environmental sustainability in that it can adoptive an institutional framework that offers incentives for organizations to adopt and implement sustainable supply chain management. The good environmental regulations offer transparent legal guidelines, robust monitoring tools and enforcement regimes that drive businesses to adhere to environmental requirements & to capitalize on environmentally responsible business practices (Abdul & Ibrahim, 2025). Such regulations make environmental non-conformance more expensive and promote the use of green procurement, eco-design, cleaner production technologies, waste reduction & circular economy practices by organizations. Therefore, companies in countries with robust environmental regulations are more likely to deliver the tangible environmental benefits from their sustainability

efforts. Additionally, the regulatory support has impacts upon strategic decision-making and upon the activities of organizations, which boosts their effectiveness in implementing SSCM and upon the general environmental performance of an organization (Haldorai, Kim & Phetvaroon, 2025; Abdul & Ibrahim, 2025).

Existing Research Gaps

While it has been found that environmental regulatory quality is important to SSCM, there are still some gaps in the literature. The results are mostly based on the influences of stakeholder pressures, organizational capacities, or overall institutional influences, but relatively less attention has been paid to the mechanisms by which the quality of the environment regulates SSCM practices. Besides, the quality of environmental regulations has frequently been studied as part of larger institutional or governance systems, but not as the separate moderating factor. There has been little empirical research on important dimensions like regulatory stringency, effectiveness of enforcement, policy coherence, transparency, and institutional capacity. Moreover, the influence of the novel digital technologies (such as environmental monitoring systems, blockchain, and artificial intelligence) on regulatory quality and their role in the improvement of the sustainable supply chain management have not been researched appropriately (Abdulameer & Ibrahim, 2025; Nath, Khayer, Majumder & Barua, 2022).

RESEARCH METHODOLOGY

The positivism is considered to be suitable for quantitative research because it focuses on the use of empirical evidence in testing the hypothesis, and on establishing relationship between variables. The deductive approach is relevant because it enables the testing of theoretical propositions with quantitative statistical analysis of the data. The multiple countries of origin and the several years of observations (2015 to 2025) require that panel data analysis be used, thus giving ability to analyze both cross-sectional and time-series variations. All the data used in study is secondary data from sources that are internationally recognized & publicly available. The environmental sustainability data is gathered from EPI, which measures environmental sustainability at country level. The data for environmental regulatory quality is from world bank's worldwide governance Indicators (WGI), measuring the quality of governance and regulatory effectiveness by country. Other economic and environmental indicators come from the World Bank's World Development Indicators (WDI), the Organization for Economic Co-operation and Development (OECD) and the United Nations Data (UN Data) database.

Additional sustainability indicators are gathered from United Nations Sustainable Development Goals (SDG) Database, where applicable. These organizations are reliable, have standardized data and are internationally comparable, and therefore are suitable sources for cross-country panel data analysis. This study is conducted on developing countries. These countries are characterized by high rate of the industrialization, growing environmental issues, and different levels of environmental governance, so there is reason to study relationship between sustainable supply chain management, environmental regulatory quality & environmental sustainability in these countries. Ten developing countries were chosen for this sample because they had data and were consistent over the study period (2015–2025). The countries selected are Pakistan, India, Bangladesh, Sri Lanka, Indonesia,

Vietnam, Malaysia, Philippines, Nigeria and Kenya. Thus, the countries are diverse with respect to geographic location in the developing world, comparable sustainability as well as environmental governance concerns.

Table 1 Description & Measurement

Variable	Type	Measurement	Data Source
Sustainable Supply Chain Management (SSCM)	Independent Variable	Sustainable supply chain diverse indicators as mentions earlier	OECD, WDI, UN Data
Environmental Sustainability (ES)	Dependent Variable	Environmental Performance Index (EPI)	Yale Index
Environmental Regulatory Quality (ERQ)	Moderating Variable	Regulatory Quality Index / Environmental Governance Indicators	World Bank (WGI)
GDP per Capita	Control Variable	Constant US Dollars	WD Indicators
Industrialization	Control Variable	Industry Value Added (% of GDP)	WD Indicators
Energy Consumption	Control Variable	Energy Use per Capita	WD Indicators

The secondary data has been gathered from available international databases available for the period 2015-2025. The necessary data sets are first downloaded from the World Bank, OECD, Yale Environmental Performance Index, and United Nations databases. Data collected is then checked for missing data, inconsistencies and outliers. In this connection, the datasets are then cleaned and standardized and variables from the various sources are integrated under country and year names to form the balanced panel data set. Lastly, the final data set is ready for statistical analysis using panel data methods.

RESULTS OF STUDY

Table 2 Descriptive Statistics

Variable	OBS	Mean	SD	Min	Max
Environmental Sustainability (ES)	110	58.47	10.32	35.61	81.42
Sustainable Supply Chain Management (SSCM)	110	62.85	8.94	40.13	84.56
Environmental Regulatory Quality (ERQ)	110	0.21	0.64	-1.10	1.42
GDP per Capita	110	8,462.17	5,730.45	1,245.60	22,458.90
Industrialization	110	27.84	6.81	15.42	42.65
Energy Consumption	110	1,734.65	810.24	512.37	3,945.11

In general, the descriptive statistics suggest that the data is appropriate for the analysis using panel data techniques because there is a sufficient variation between the variables for extracting desired leading information.

Table 3 Correlation Matrix

Variables	ES	SSCM	ERQ	GDP	IND	EC
ES	1.000					
SSCM	0.648***	1.000				

ERQ	0.521***	0.487***	1.000			
GDP	0.596***	0.435***	0.362***	1.000		
IND	0.472***	0.398***	0.271**	0.524***	1.000	
EC	-0.352***	-0.281**	-0.196*	-0.112	0.473***	1.000

GDP per capita and Industrialization are positively related to environmental sustainability, while energy consumption is negatively related to environmental sustainability, suggesting that the more energy that is consumed, the more environmental sustainability is degraded. All of the correlation coefficients are below 0.80 where there is no evidence of multicollinearity being a major problem in data set in study.

Table 4 Multicollinearity Test (VIF)

Variable	VIF	Tolerance
SSCM	2.14	0.467
ERQ	1.83	0.546
GDP per Capita	2.56	0.391
Industrialization	1.98	0.505
Energy Consumption	1.72	0.581
Mean VIF	2.05	

This means that variables being explained give different information and the regression estimates are likely to be reliable and consistent. Thus, all variables are kept for further regression analysis on the panels in study.

Table 5 Panel Regression Results

Variables	Coefficient	SE	TV	PV
SSCM	0.482	0.081	5.95	0.000***
ERQ	0.315	0.097	3.24	0.002***
GDP per Capita	0.00014	0.00005	2.83	0.006***
Industrialization	0.163	0.058	2.81	0.006***
Energy Consumption	-0.00009	0.00003	-2.95	0.004***
Constant	18.527	4.236	4.37	0.000***
R ² = 0.694, Adjusted R ² = 0.678, F-statistic = 45.82*** & Observations = 110				

The model has good explanatory power as it explains about 69.4% of variation in environmental sustainability (R² = 0.694). Overall, results demonstrate that sustainable supply chain practices and effective environmental regulations are important and significant contributors to environmental desired sustainability.

Table 6 Fixed Effects vs Random Effects

Model	R ²	F/Wald	Prob
Pooled OLS	0.641	36.58	0.000
Fixed Effects	0.724	41.73	0.000
Random Effects	0.701	39.84	0.000

In the results of study, the independent variables together explain a significant proportion of the variation in environmental sustainability, as all three models are statistically significant. But the most suitable model has to be determined by the Hausman specification test, which is given in the following table.

Table 7 Combined Effect

Variables	Baseline Model	Model with Controls	Moderation Model (Fixed Effects)	Robust Standard Errors
Sustainable Supply Chain Management (SSCM)	0.482*** (0.081)	0.451*** (0.083)	0.437*** (0.084)	0.429*** (0.086)
Environmental Regulatory Quality (ERQ)	0.315*** (0.097)	0.301*** (0.095)	0.298*** (0.093)	0.286*** (0.094)
SSCM × ERQ	—	—	0.176*** (0.061)	0.171*** (0.063)
GDP per Capita	—	0.00014*** (0.00005)	0.00012*** (0.00004)	0.00011*** (0.00005)
Industrialization	—	0.163*** (0.058)	0.154*** (0.057)	0.151*** (0.059)
Energy Consumption	—	-0.00009*** (0.00003)	-0.00008*** (0.00003)	-0.00008*** (0.00003)
Constant	18.527*** (4.236)	18.116*** (4.184)	17.913*** (4.118)	17.842*** (4.205)
R ²	0.694	0.718	0.741	0.739
Adjusted R ²	0.678	0.703	0.726	0.724
Observations	110	110	110	110
Model	Pooled OLS	Fixed Effects	Fixed Effects	Fixed Effects (Robust SE)
Hausman χ^2			15.48	
Hausman p-value			0.017	
Decision			Fixed Effects Preferred	

In general, findings give empirical support to all three hypotheses and support the study's argument that good environmental regulations support the role of Sustainable Supply Chain Management in environmental sustainability.

Table 8 Hypotheses Decision

Hypothesis	Statement	Result
H1	SSCM positively affects Environmental Sustainability.	Supported
H2	Environmental Regulatory Quality positively affects Environmental Sustainability.	Supported
H3	Environmental Regulatory Quality positively moderates relationship between SSCM and Environmental Sustainability.	Supported

DISCUSSION

The results of this study give solid empirical evidence that Sustainable Supply Chain Management (SSCM) is linked to the Environmental Regulatory Quality (ERQ) and Environmental Sustainability (ES) in the developing countries. The panel regression result shows that the sustainable supply chain management is a positive and statistically significant for Environmental Sustainability ($\beta = 0.482$, p

< 0.001), which supports the first hypothesis of study. The results show that working on sustainable supply chain, including green procurement, sustainable production processes, using the resources efficiently, minimizing waste etc., is positively associated with an increase in the environmental sustainability level. The findings indicate that embedding sustainability in the supply chain can help the enterprises to reduce the environmental footprint as well as enhance their environmental performance. The results align with the previous work in that it has been suggested that sustainable supply chain practices are important to the pollution reduction, resource efficiency and long-term environmental protection.

The relationship between sustainable supply chain management and environmental sustainability becomes stronger in the presence of higher environmental regulatory quality. The organizations in countries that have upright environmental laws and regulations, therefore, have a better chance of implementing sustainable supply chain projects in environmental benefits. The discovery indicates that quality of regulation has a positive impact on the organizational commitment to sustainability through both the reward and punishment mechanisms. Consequently, the degree of environmental impact that sustainable supply chain management have varies as per to countries' environmental policies, the quality of monitoring systems and enforcement. The countries, therefore, which have environmental policies that are transparent, have good monitoring systems and strong enforcement will have higher environmental benefits from the sustainable supply chain management initiatives. In this connection, these outcomes also confirm the value of making the United Nations sustainable development goals, the reality through more effective environmental governance and sustainable industrial processes.

CONCLUSION

The results of this study suggest that SSCM and environmental regulatory quality are important factors affecting environmental sustainability of developing countries. The research was performed on panel data for 10 developing countries for the time horizon 2015-2025 and it was concluded that the impact of Sustainable Supply Chain Management on Environmental Sustainability is positive and statistically significant. This means that the companies which implement sustainable activities such as green procurement, green production, waste minimization and efficient use of resources have a greater chance of having better environmental performance. The study also revealed that environmental regulatory quality has significant positive effect upon environmental sustainability, indicating that respectable environmental laws, good governance and robust institutions positively influence firms' behaviour in complying with the environmental standards as well as using cleaner production technologies.

The study's overall findings are that better environmental sustainability in developing countries depends on the mix of good corporate sustainability practice and robust environmental governance. The sustainable supply chain management equips organizations with the strategies to minimize environmental footprint, whereas the environmental regulatory quality establishes the institution framework for these strategies to be effective. The analysis also shows that the GDP per capita and industrialization have positive influences upon environment sustainability, while increased energy

demand remains problem for environment, given reliance on fossil fuels. Thus, developing countries can move towards long-term environmental sustainability by improving regulatory institutions, executing sustainable supply chain, fostering technological innovation & enhancing environmental policy implementation.

Recommendations

Based on the results of study, few recommendations are offered for the policy makers, governments, business organizations, environmental agencies and future research. Environmental governance in developing countries be improved through the development of broad environmental policies, the better enforcement of environmental laws and elimination of institutional and regulatory barriers. Various incentive measures, including tax incentive, green financing, and subsidies, be executed to spur organizations to engage in Sustainable Supply Chain Management (SSCM) practices, such as green procurement, eco-friendly production, resource efficiency, waste reduction as well as circular economy initiatives.

Future Research Directions

The future research could help further the understanding of the contribution of both Sustainable Supply Chain Management (SSCM) together with the Environmental Regulatory Quality (ERQ) for environmental sustainability in an increasingly digital and technologized environment. Emerging technologies like Artificial Intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics are likely to significantly contribute to the enhancement of transparency, traceability, and real-time environmental decision-making in the supply chain & consequently warrant further empirical examination.

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