



Sustainable Supply Chain Management and Firm Efficiency: Assessing the Trade-Off between Cost Competitiveness and Environmental Responsibility

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ABSTRACT

This study investigates the relationship between Sustainable Supply Chain Management (SSCM) practices and firm efficiency, with a particular focus on the trade-off between cost competitiveness and environmental responsibility in Pakistani manufacturing firms. Grounded in stakeholder theory, the natural resource-based view (NRBV), and institutional theory, the research employs a quantitative, survey-based methodology. Primary data were collected from 320 respondents across manufacturing industries in Pakistan using a structured questionnaire. Statistical analyses were conducted using STATA 17, including descriptive statistics, confirmatory factor analysis (CFA), regression analysis, and structural equation modelling (SEM). Findings reveal that green procurement, eco-design, reverse logistics, and environmental collaboration significantly influence firm efficiency. While SSCM adoption imposes short-run cost pressures, firms that strategically integrate environmental responsibility into supply chain operations achieve long-run efficiency gains and competitive advantages. The study contributes to the growing literature on sustainability in emerging market contexts and provides actionable recommendations for managers and policymakers.



1. Introduction

The escalating global concern over climate change, resource depletion, and environmental degradation has fundamentally transformed the operational imperatives of contemporary business organisations. Firms operating across diverse industries are increasingly compelled to reassess their supply chain architectures in light of mounting regulatory pressures, evolving stakeholder expectations, and intensifying scrutiny from civil society (Seuring & Muller, 2008; Carter & Rogers, 2008). Sustainable Supply Chain Management (SSCM) has emerged as a central construct

in this discourse, embodying the integration of environmental, social, and economic dimensions into the design and management of supply chain processes (Ahi & Searcy, 2013).

Despite the growing normative acceptance of sustainability principles, firms—particularly those operating in cost-sensitive, developing economy contexts—face a fundamental dilemma: the adoption of environmentally responsible supply chain practices often entails significant upfront investments, process reconfigurations, and supplier compliance costs that can erode short-term cost competitiveness (Zhu & Sarkis, 2004; Diabat & Govindan, 2011). This tension between environmental stewardship and economic efficiency represents one of the most contested empirical and managerial debates in the extant literature.

Existing research, predominantly conducted in the context of developed economies, has yielded mixed findings. While some studies document a positive relationship between SSCM adoption and firm performance (Green et al., 2012; Liang & Wu, 2020), others suggest that the trade-off between sustainability and cost efficiency persists, particularly in resource-constrained environments (Walker et al., 2008; Luthra et al., 2015). The dearth of empirical evidence from emerging markets such as Pakistan—where manufacturing constitutes a significant share of economic output but environmental governance remains nascent—represents a substantial gap in the literature.

This study seeks to address this gap through a quantitative survey analysis of manufacturing firms in Pakistan. Drawing upon stakeholder theory (Freeman, 1984), the natural resource-based view (Hart, 1995), and institutional theory (DiMaggio & Powell, 1983), the research examines how SSCM practices specifically green procurement, eco-design, reverse logistics, and environmental collaboration influence firm efficiency, measured through operational cost efficiency and competitive positioning. The empirical analysis employs STATA 17 to execute regression modelling, structural equation modelling, and mediation analyses.

The remainder of this paper is structured as follows: Section 2 provides a comprehensive review of the relevant literature and develops the theoretical framework. Section 3 presents the research methodology. Section 4 discusses the empirical results. Section 5 interprets the findings in light of the theoretical framework and prior empirical evidence. Section 6 concludes with implications, limitations, and directions for future research.

2. Literature Review and Theoretical Framework

2.1 Conceptualising Sustainable Supply Chain Management

Sustainable Supply Chain Management is broadly defined as the management of material, information, and capital flows, as well as cooperation among companies along the supply chain, while taking goals from all three dimensions of sustainable development economic, environmental, and social into account (Seuring & Muller, 2008, p. 1700). The concept extends traditional supply chain management by embedding sustainability considerations at every node of the value chain, from raw material extraction to end-of-life product disposal (Srivastava, 2007; Beske & Seuring, 2014; Latif, 2025).

Green Supply Chain Management (GSCM) a closely related construct has received considerable attention as the environmental subset of SSCM (Zhu et al., 2008). GSCM encompasses practices such as green procurement, green manufacturing, green distribution, and reverse logistics, each aimed at reducing the environmental footprint of supply chain operations (Rao & Holt, 2005). The evolution from GSCM to the broader SSCM paradigm reflects a more holistic recognition of the interconnectedness between environmental performance, social equity, and economic viability.

Scholars have identified several key dimensions of SSCM, including: (1) green procurement and supplier selection based on environmental criteria; (2) eco-design and product lifecycle considerations; (3) reverse logistics and closed-loop supply chains; (4) environmental collaboration with supply chain partners; and (5) carbon footprint management and emissions reporting (Sarkis et al., 2011; Gimenez & Tachizawa, 2012). Each of these dimensions interacts with firm-level efficiency outcomes through distinct mechanisms that this study seeks to empirically delineate.

2.2 Firm Efficiency in the Sustainability Context

Firm efficiency, as conceptualised in this study, encompasses both operational cost efficiency—the ability to minimise input costs per unit of output and competitive efficiency, reflecting the firm's capacity to sustain or enhance its market position relative to competitors (Porter & van der Linde, 1995). The relationship between SSCM adoption and firm efficiency is theoretically ambiguous. On one hand, environmental investments impose compliance costs, disrupt established supplier relationships, and demand managerial attention and organisational reconfiguration (Walley & Whitehead, 1994). On the other hand, proponents of the Porter hypothesis argue that well-designed environmental regulations and voluntary sustainability commitments can stimulate innovation, resource efficiency, and ultimately superior competitive performance (Porter & van der Linde, 1995; Ambec & Lanoie, 2008).

Empirical evidence supporting the 'win-win' thesis—that environmental performance and economic performance are complementary rather than antagonistic—has grown substantially over the past two decades. Meta-analytical evidence reported by Albertini (2013) across 52 studies confirms a positive but contextually contingent relationship between environmental performance and financial performance. Similarly, Green et al. (2012) demonstrate that GSCM practices positively impact economic performance in Chinese manufacturing firms through the mediating role of operational efficiency.

2.3 Theoretical Framework

This study draws upon three complementary theoretical lenses to construct its analytical framework.

The Natural Resource-Based View (NRBV), advanced by Hart (1995) as an extension of Barney's (1991) resource-based view, posits that sustainable competitive advantage is derived from firm capabilities oriented toward environmental stewardship. Hart identifies three interconnected strategies pollution prevention, product stewardship, and sustainable development each associated with distinct competitive outcomes. In the context of SSCM, firms that embed environmental capabilities into their supply chain routines can develop inimitable organisational competencies that generate long-run efficiency advantages.

Stakeholder Theory (Freeman, 1984) provides a complementary lens by highlighting the role of diverse stakeholder demands including regulatory bodies, customers, investors, and communities in shaping firm behaviour toward SSCM adoption. Firms that are responsive to stakeholder environmental expectations are better positioned to manage reputational risks, secure preferential market access, and build relational capital with environmentally conscious supply chain partners (Clarkson, 1995; Bowen, 2000).

Institutional Theory (DiMaggio & Powell, 1983) explains SSCM adoption as a response to coercive (regulatory mandates), normative (professional and industry norms), and mimetic (imitation of successful peers) pressures. In emerging economies, institutional pressures from

multinational corporations and global supply chain standards have been documented as significant drivers of SSCM practices among domestic suppliers (Liu et al., 2010; Zhu et al., 2013).

2.4 Hypothesis Development

Based on the theoretical framework and empirical evidence, the following hypotheses are advanced:

H1: Green procurement practices are positively associated with firm operational efficiency.

H2: Eco-design practices are positively associated with firm operational efficiency.

H3: Reverse logistics practices are positively associated with firm operational efficiency.

H4: Environmental collaboration with supply chain partners is positively associated with firm operational efficiency.

H5: SSCM practices are negatively associated with short-term cost competitiveness.

H6: The relationship between SSCM practices and firm efficiency is mediated by environmental innovation capability.

H7: Institutional pressures moderate the relationship between SSCM practices and firm efficiency, such that stronger institutional pressures amplify the efficiency gains from SSCM adoption.

These hypotheses collectively capture both the direct and conditional pathways through which SSCM practices influence firm efficiency, enabling a nuanced empirical test of the cost-competitiveness trade-off.

2.5 Review of Empirical Evidence

Green et al. (2012) conducted a large-scale survey of Chinese manufacturers and found that GSCM practices, including green purchasing and cooperation with customers, significantly enhance both environmental and economic performance. Liang and Wu (2020) extend this evidence to the service sector, demonstrating that SSCM adoption improves operational efficiency through process standardisation and waste reduction. Zhu et al. (2008) document that Chinese firms adopting reverse logistics and closed-loop supply chain practices achieve measurable reductions in material input costs.

In contrast, Walker et al. (2008) identify numerous barriers to SSCM adoption in UK public sector procurement, including cost premiums, supplier capability gaps, and institutional inertia. Luthra et al. (2015) similarly document cost-efficiency trade-offs in Indian automotive supply chains, where small and medium-sized enterprises (SMEs) struggle to absorb the compliance costs associated with environmental certification requirements.

The Pakistani context presents unique features. The manufacturing sector—particularly textiles, cement, chemicals, and leather accounts for approximately 19% of GDP and employs over 15 million workers, yet operates under relatively weak environmental governance frameworks (State Bank of Pakistan, 2022). The recent adoption of Pakistan's National Environmental Policy (2005) and sectoral environmental standards by the Pakistan Environmental Protection Agency (PEPA) has introduced new regulatory pressures, while the proliferation of export-oriented supply chains linked to European and North American buyers has generated normative pressures for SSCM compliance. These contextual dynamics make Pakistan an ideal empirical laboratory for testing the SSCM-efficiency relationship.

3. Research Methodology

3.1 Research Design

This study adopts a quantitative, cross-sectional survey design to empirically test the hypothesised relationships between SSCM practices and firm efficiency. The positivist epistemological stance, combined with a deductive research approach, is appropriate for hypothesis testing in contexts where well-developed theoretical models provide clear directional predictions (Bryman & Bell, 2015). The use of survey methodology is consistent with established practice in SSCM research (Zhu et al., 2008; Green et al., 2012; Luthra et al., 2015).

3.2 Population and Sampling

The target population comprises manufacturing firms operating in Pakistan across five major sectors: textiles and apparel, chemicals and pharmaceuticals, food and beverages, cement and construction materials, and engineering goods. These sectors were selected based on their significance to Pakistan's industrial output, their integration into global supply chains, and their documented environmental impacts (Pakistan Bureau of Statistics, 2023).

A stratified random sampling approach was employed to ensure proportional representation across sectors and firm size categories (small, medium, and large enterprises as defined by the Small and Medium Enterprises Development Authority, SMEDA). A total of 450 questionnaires were distributed through two channels: direct administration at industrial estates in Karachi, Lahore, Faisalabad, and Sialkot, and an online survey distributed through industry associations. Of the 450 questionnaires distributed, 335 were returned, yielding a response rate of 74.4%. After excluding incomplete responses and detecting multivariate outliers through Mahalanobis distance analysis in STATA, a final usable sample of 320 responses was retained for analysis.

The sample size of 320 satisfies the minimum recommended threshold for structural equation modelling applications, which require at least 10 observations per estimated parameter, and is consistent with the recommendations of Hair et al. (2019) for covariance-based SEM analyses with up to 40 indicators.

3.3 Measurement Instrument

The questionnaire was developed through a systematic process of item generation from existing validated scales, expert panel review, cognitive interviewing with five industry practitioners, and a pilot test with 30 respondents. All items were measured on a five-point Likert scale anchored at 1 (Strongly Disagree) to 5 (Strongly Agree).

Green Procurement (GP) was measured using six items adapted from Zhu et al. (2008) and Bowen et al. (2001), capturing the extent to which firms integrate environmental criteria into supplier selection and purchasing decisions. Eco-Design (ED) was assessed with five items adapted from Srivastava (2007), reflecting the degree to which environmental considerations are incorporated into product and process design. Reverse Logistics (RL) was measured with five items adapted from Rogers and Tibben-Lembke (2001), capturing practices related to product returns, remanufacturing, and recycling. Environmental Collaboration (EC) was measured with four items adapted from Gimenez and Tachizawa (2012), assessing the extent of environmental cooperation with upstream suppliers and downstream customers.

Firm Operational Efficiency (FOE) was measured with six items developed from the scales of Rao and Holt (2005) and Green et al. (2012), capturing cost reduction in purchasing, production, and logistics. Cost Competitiveness (CC) was assessed with five items reflecting the firm's perceived ability to compete on cost in its primary markets. Environmental Innovation Capability (EIC) was

measured with four items adapted from Chen et al. (2006). Institutional Pressure (IP) was measured with six items capturing regulatory, normative, and mimetic pressures, adapted from Zhu et al. (2013).

3.4 Analytical Approach

All statistical analyses were conducted using STATA 17. The analytical sequence comprised the following stages:

Stage 1 – Descriptive Statistics: Means, standard deviations, and correlation matrices were computed for all study variables. Variance Inflation Factors (VIF) were examined to detect multicollinearity.

Stage 2 – Measurement Model Assessment: Confirmatory factor analysis (CFA) was performed using the sem command in STATA 17 to evaluate construct validity. Convergent validity was assessed through average variance extracted (AVE) and composite reliability (CR). Discriminant validity was assessed through the Fornell-Larcker criterion and Heterotrait-Monotrait (HTMT) ratios.

Stage 3 – Hypothesis Testing: Ordinary Least Squares (OLS) regression models were estimated to test H1-H5, with robust standard errors to correct for heteroskedasticity (detected via the Breusch-Pagan test). The bootstrapped mediation analysis (1,000 repetitions) was conducted using the Sobel test and the medeff command to test H6. Moderated regression analysis with interaction terms was employed to test H7.

Stage 4 – Robustness Checks: Alternative model specifications, sub-sample analyses by sector and firm size, and common method bias assessment using Harman's single-factor test and the marker variable technique were conducted to evaluate the robustness of findings.

4. Results

4.1 Respondent Profile

Table 1 presents the demographic and organisational characteristics of the sample. The sample was predominantly male (71.6%), reflecting the gender composition of managerial roles in Pakistani manufacturing. Middle managers constituted the largest respondent category (44.1%), followed by senior managers (32.8%) and operational managers (23.1%). The textiles sector accounted for the highest proportion of respondents (31.3%), consistent with its dominance in Pakistani manufacturing. Large enterprises (500+ employees) constituted 38.4% of the sample, medium enterprises (100-499 employees) 34.1%, and small enterprises (less than 100 employees) 27.5%.

Table 1: Respondent and Firm Profile (N = 320)

Characteristic	Category	Frequency (%)
Gender	Male	229 (71.6%)
	Female	91 (28.4%)
Managerial Level	Senior Manager	105 (32.8%)
	Middle Manager	141 (44.1%)
	Operational Manager	74 (23.1%)
Sector	Textiles & Apparel	100 (31.3%)
	Chemicals & Pharma	62 (19.4%)
	Food & Beverages	58 (18.1%)
	Cement & Construction	48 (15.0%)
	Engineering Goods	52 (16.3%)

Firm Size	Small (<100 employees)	88 (27.5%)
	Medium (100–499)	109 (34.1%)
	Large (500+)	123 (38.4%)
Years in Operation	< 5 years	32 (10.0%)
	5–15 years	128 (40.0%)
	> 15 years	160 (50.0%)

4.2 Descriptive Statistics and Correlation Analysis

Table 2 presents the means, standard deviations, and Pearson correlation coefficients for all study variables. The mean scores for SSCM practice dimensions range from 3.12 (Eco-Design) to 3.68 (Green Procurement), indicating moderate to moderately high adoption levels. Firm Operational Efficiency exhibits a mean of 3.44, suggesting moderate perceived efficiency. Cost Competitiveness scores ($M = 3.29$) indicate that respondents perceive some negative pressure from SSCM adoption on cost efficiency, consistent with H5. All inter-construct correlations are statistically significant at the 0.01 level, and no correlation exceeds 0.75, providing preliminary evidence against multicollinearity concerns.

Table 2: Descriptive Statistics and Correlation Matrix

Variable	M	SD	GP	ED	RL	EC	FOE	CC
1. Green Procurement (GP)	3.68	0.71	1.00					
2. Eco-Design (ED)	3.12	0.83	0.61**	1.00				
3. Reverse Logistics (RL)	3.34	0.79	0.57**	0.63**	1.00			
4. Envir. Collab. (EC)	3.47	0.68	0.65**	0.58**	0.61**	1.00		
5. Firm Oper. Efficiency (FOE)	3.44	0.74	0.52**	0.48**	0.54**	0.59**	1.00	
6. Cost Competitiveness (CC)	3.29	0.81	−0.31**	−0.27**	−0.22**	−0.18**	0.43**	1.00

Note. ** $p < .01$ (two-tailed). M = mean; SD = standard deviation.

4.3 Measurement Model Assessment

The CFA results confirm satisfactory model fit: $\chi^2/df = 2.31$, CFI = 0.954, TLI = 0.947, RMSEA = 0.064 [90% CI: 0.053, 0.075], SRMR = 0.058. These indices meet or exceed the conventional thresholds recommended by Hair et al. (2019). Table 3 presents the factor loadings, AVE, and CR estimates for each construct.

Table 3: Measurement Model – Convergent Validity

Construct / Item	Std. Loading	t-value	AVE	CR
Green Procurement			0.583	0.891
GP1: Env. criteria in supplier selection	0.812	18.43		
GP2: Environmental audit of suppliers	0.793	17.21		
GP3: Green specifications in purchasing	0.741	15.88		
GP4: Supplier environmental certification	0.718	15.01		
GP5: Purchasing from ISO 14001-certified	0.699	14.32		
GP6: Life cycle cost assessment	0.722	15.14		
Eco-Design			0.561	0.863

ED1: Design for disassembly	0.784	16.98		
ED2: Use of recycled materials	0.761	16.11		
ED3: Design for reuse	0.742	15.57		
ED4: Energy-efficient product design	0.718	14.99		
ED5: Reduced hazardous material use	0.701	14.43		
Reverse Logistics			0.548	0.857
RL1: Product return management	0.771	16.52		
RL2: Remanufacturing/refurbishment	0.758	16.02		
RL3: Recycling and waste disposal	0.731	15.28		
RL4: Closed-loop packaging	0.712	14.73		
RL5: Reverse logistics partnerships	0.698	14.26		
Environmental Collaboration			0.572	0.843
EC1: Joint environmental planning	0.802	17.44		
EC2: Env. targets with suppliers	0.769	16.63		
EC3: Green information sharing	0.741	15.86		
EC4: Environmental audits with partners	0.702	14.57		
Firm Operational Efficiency			0.564	0.885
FOE1: Reduced purchasing costs	0.791	17.18		
FOE2: Lower inventory costs	0.771	16.62		
FOE3: Energy cost reduction	0.748	15.94		
FOE4: Logistics cost savings	0.729	15.31		
FOE5: Reduced waste disposal costs	0.712	14.72		
FOE6: Overall operational efficiency	0.698	14.27		
Cost Competitiveness			0.541	0.851
CC1: Ability to offer competitive prices	0.768	16.43		
CC2: Cost parity with competitors	0.748	15.88		
CC3: Profit margin maintenance	0.731	15.31		
CC4: Price leadership potential	0.712	14.73		
CC5: Cost recovery timeline	0.691	14.11		

Note. AVE = Average Variance Extracted; CR = Composite Reliability. All loadings significant at $p < .001$.

All standardised factor loadings exceed the 0.70 threshold, AVE values range from 0.541 to 0.583 (all above the 0.50 benchmark), and CR values range from 0.843 to 0.891 (all above the 0.70 benchmark), collectively confirming convergent validity. Discriminant validity was established as the square root of AVE for each construct exceeded its correlations with all other constructs (Fornell & Larcker, 1981). HTMT ratios for all construct pairs remained below 0.85, further corroborating discriminant validity (Henseler et al., 2015).

4.4 Hypothesis Testing – Regression Analysis

OLS regression results testing H1 through H5 are presented in Table 4. The dependent variable in Models 1-4 is Firm Operational Efficiency (FOE), while Model 5 uses Cost Competitiveness (CC) as the dependent variable. Control variables include firm size (log of employee count), firm age, sector dummies, and ISO 14001 certification status.

Table 4: OLS Regression Results (STATA 17)

Predictor	Model 1 FOE	Model 2 FOE	Model 3 FOE	Model 4 FOE	Model 5 CC
Green Procurement (GP)	0.341*** (0.058)			0.198*** (0.061)	-0.219*** (0.072)
Eco-Design (ED)		0.287*** (0.063)		0.163** (0.066)	-0.181** (0.078)
Reverse Logistics (RL)			0.318*** (0.061)	0.211*** (0.063)	-0.142* (0.074)
Env. Collaboration (EC)				0.257*** (0.068)	-0.098 (0.081)
Firm Size (log)	0.112* (0.048)	0.108* (0.049)	0.115* (0.048)	0.101* (0.047)	0.132** (0.056)
Firm Age	0.031 (0.022)	0.028 (0.022)	0.033 (0.022)	0.027 (0.022)	0.041 (0.026)
ISO 14001 Certified	0.193*** (0.052)	0.181*** (0.053)	0.188*** (0.052)	0.171*** (0.051)	0.089 (0.062)
Constant	1.421*** (0.213)	1.652*** (0.221)	1.538*** (0.218)	0.891*** (0.241)	2.974*** (0.287)
Observations	320	320	320	320	320
R ²	0.348	0.291	0.324	0.421	0.237
Adj. R ²	0.331	0.273	0.307	0.402	0.217
F-statistic	29.84***	23.18***	27.01***	31.96***	17.42***
VIF (max)	1.82	1.78	1.84	2.11	2.13

*Note. Robust standard errors in parentheses. Sector dummies included but not reported. * $p < .05$; ** $p < .01$; *** $p < .001$.*

Model 4, the full SSCM model, explains 42.1% of the variance in Firm Operational Efficiency (Adj. $R^2 = 0.402$). Green Procurement ($\beta = 0.198$, $p < .001$) provides the strongest effect on operational efficiency, supporting H1. Eco-Design ($\beta = 0.163$, $p < .01$) supports H2, Reverse Logistics ($\beta = 0.211$, $p < .001$) supports H3, and Environmental Collaboration ($\beta = 0.257$, $p < .001$) provides the largest effect, supporting H4. Model 5 reveals that SSCM dimensions exert negative effects on Cost Competitiveness: Green Procurement ($\beta = -0.219$, $p < .001$), Eco-Design ($\beta = -0.181$, $p < .01$), and Reverse Logistics ($\beta = -0.142$, $p < .05$), lending support to H5. Environmental Collaboration does not significantly predict Cost Competitiveness ($\beta = -0.098$, $p > .05$), suggesting that collaborative sustainability efforts do not impose measurable cost penalties. Maximum VIF values remain below 3.0 across all models, confirming the absence of problematic multicollinearity.

4.5 Mediation Analysis – Environmental Innovation Capability

Table 5 presents the bootstrapped mediation results for H6, testing whether Environmental Innovation Capability (EIC) mediates the relationship between the SSCM composite score and Firm Operational Efficiency. The SSCM composite was computed as the mean of all four SSCM dimensions following the CFA confirmation of construct validity.

Table 5: Mediation Analysis Results (Bootstrapped, 1,000 repetitions)

Path	Coefficient	SE	95% CI Lower	95% CI Upper
SSCM → EIC (a path)	0.512***	0.071	0.372	0.652
EIC → FOE (b path)	0.381***	0.063	0.257	0.505
SSCM → FOE (direct, c' path)	0.218***	0.069	0.082	0.354
Indirect effect (a×b)	0.195***	0.044	0.112	0.284
Total effect (c path)	0.413***	0.071	0.273	0.553
Proportion mediated	47.2%			

Note. *** $p < .001$. CI = Confidence Interval; EIC = Environmental Innovation Capability; FOE = Firm Operational Efficiency; SE = Standard Error.

The indirect effect of SSCM on FOE through EIC is statistically significant ($\beta = 0.195$, 95% CI [0.112, 0.284]), as the confidence interval does not include zero. EIC mediates 47.2% of the total SSCM-FOE relationship, indicating partial mediation. The direct effect remains significant ($\beta = 0.218$, $p < .001$), suggesting that SSCM also exerts direct efficiency benefits not fully channelled through innovation. H6 is thus supported.

4.6 Moderation Analysis – Institutional Pressure

Table 6 presents the moderated regression results for H7, examining whether Institutional Pressure (IP) moderates the SSCM-FOE relationship. The SSCM composite and Institutional Pressure scale were mean-centred before computing the interaction term to minimise multicollinearity.

Table 6: Moderated Regression – Institutional Pressure as Moderator

Variable	Model A β	Model B β	Model C β	ΔR^2
SSCM Composite	0.421***	0.408***	0.396***	
Institutional Pressure (IP)		0.311***	0.298***	
SSCM × IP (Interaction)			0.183**	
Controls	Yes	Yes	Yes	
R^2	0.382	0.443	0.471	
ΔR^2 (vs previous model)		0.061***	0.028**	0.028**
F-change		34.88***	16.74**	

Note. ** $p < .01$; *** $p < .001$. Dependent variable: Firm Operational Efficiency. SSCM and IP mean-centred.

The interaction term (SSCM × IP) is positive and statistically significant ($\beta = 0.183$, $p < .01$), explaining an additional 2.8% of variance in Firm Operational Efficiency ($\Delta R^2 = 0.028$, $p < .01$). This confirms H7: firms operating under stronger institutional pressures derive greater efficiency gains from SSCM adoption. The interaction is depicted in a simple slope analysis (not tabulated), where the positive SSCM-FOE slope is steeper at high (+1 SD) institutional pressure levels than at low (−1 SD) levels, consistent with theoretical expectations.

4.7 Robustness Checks

Common method bias was assessed using Harman's single-factor test, which explained 23.4% of variance—well below the 50% threshold—suggesting that common method bias does not pose a serious threat. The marker variable technique (using a theoretically unrelated variable: respondent commute time to work) confirmed that construct correlations remained substantively unchanged after partialling out the marker variable (maximum change in $r = 0.03$). Sub-sample analyses by sector (textiles vs. non-textiles) and firm size (SME vs. large) confirmed directionally consistent findings, with some attenuation of effect sizes for small firms, consistent with resource constraint

arguments. Alternative operationalisation of FOE using a financial performance composite (return on assets, profit margin self-reports) yielded directionally consistent but weaker coefficients, reflecting the well-documented lag between sustainability investments and financial returns.

5. Discussion

5.1 Interpretation of Main Findings

The empirical results of this study reveal a nuanced picture of the SSCM-efficiency nexus in Pakistani manufacturing. The positive and significant effects of all four SSCM dimensions—green procurement, eco-design, reverse logistics, and environmental collaboration—on firm operational efficiency (H1-H4 supported) align with the predictions of the NRBV and empirical findings from comparable developing economy studies (Green et al., 2012; Liang & Wu, 2020; Diabat & Govindan, 2011). These findings affirm that SSCM adoption is not merely a compliance-driven cost burden but can generate tangible efficiency improvements through mechanisms such as waste reduction, energy savings, process innovation, and supplier quality enhancement.

The positive effect of green procurement on operational efficiency (H1) is consistent with the argument that rigorous environmental supplier selection generates higher-quality inputs, reduces defect rates, and minimises supply disruption risks associated with non-compliant suppliers (Bowen et al., 2001). The particularly strong effect of environmental collaboration on efficiency (H4, $\beta = 0.257$) supports Gimenez and Tachizawa's (2012) contention that buyer-supplier environmental collaboration creates joint value through information sharing, coordinated process improvements, and shared environmental investment costs.

The negative association between SSCM dimensions and cost competitiveness (H5 partially supported) provides empirical validation of the trade-off thesis advanced by Walley and Whitehead (1994) and documented in developing economy contexts by Luthra et al. (2015). Green procurement and eco-design impose the largest cost competitiveness penalties, reflecting the premium prices associated with certified green inputs and the R&D investments required for eco-design implementation. That environmental collaboration does not significantly predict cost competitiveness deterioration suggests that collaborative sustainability arrangements—rather than unilateral compliance investments—may represent a more cost-efficient pathway to SSCM adoption.

The partial mediation through Environmental Innovation Capability (H6 supported) is theoretically significant. It indicates that SSCM practices stimulate firms to develop new environmental technologies, processes, and routines that subsequently improve operational efficiency. This finding resonates with Porter and van der Linde's (1995) innovation offset hypothesis and Chen et al.'s (2006) empirical evidence from Taiwanese electronics manufacturers. The 47.2% mediation proportion implies that nearly half of SSCM's efficiency dividend is contingent on firms successfully translating sustainability commitments into innovative capabilities—a non-trivial requirement that underscores the importance of organisational absorptive capacity.

The positive moderation by institutional pressure (H7 supported) offers important insights into the institutional drivers of SSCM performance. Firms facing stronger regulatory and normative pressures develop more sophisticated environmental management systems, invest more in sustainability-oriented human capital, and signal environmental credibility more effectively to market stakeholders, all of which amplify the efficiency returns to SSCM adoption (Zhu et al., 2013; Liu et al., 2010).

5.2 Theoretical Contributions

This study makes three primary theoretical contributions. First, it extends the NRBV to the Pakistani manufacturing context, empirically validating the proposition that supply chain-level environmental capabilities generate operational efficiency advantages in an emerging economy setting characterised by weak institutional infrastructure and resource constraints. Second, by integrating stakeholder theory and institutional theory into the analytical framework, the study provides a more comprehensive account of the multi-level drivers of the SSCM-efficiency relationship than single-theoretical perspectives permit. Third, the mediation-moderation architecture of the research model generates novel insights into the conditional pathways through which SSCM practices translate into efficiency outcomes, advancing beyond the bivariate analyses that dominate much of the GSCM literature.

5.3 Practical Implications

The findings carry several implications for managers and policymakers. For managers, the results suggest that SSCM adoption should not be conceptualised primarily as a cost centre but as a strategic investment in operational capability development. The efficiency gains documented—particularly through environmental collaboration and reverse logistics—are achievable within the short-to-medium term and can partially offset the cost competitiveness penalties of green procurement and eco-design. Firms are advised to prioritise collaborative SSCM strategies over unilateral compliance investments as a cost-effective entry point into sustainable supply chain transformation.

For policymakers, the moderating role of institutional pressure suggests that the regulatory environment matters significantly for SSCM performance outcomes. Strengthening environmental enforcement mechanisms, providing fiscal incentives for SSCM investment (e.g., tax credits for ISO 14001 certification, subsidies for reverse logistics infrastructure), and fostering industry-level sustainability standards can accelerate the diffusion of efficiency-enhancing SSCM practices. The Pakistan Environmental Protection Agency (PEPA) and the Board of Investment (BOI) should collaborate to design incentive structures that reduce the short-term cost barriers to SSCM adoption, particularly for SMEs that exhibit attenuated efficiency gains due to resource constraints.

5.4 Limitations and Future Research Directions

Several limitations of this study warrant acknowledgement. First, the cross-sectional design precludes causal inferences and does not capture the temporal dynamics of SSCM implementation and efficiency outcomes. Longitudinal panel data designs would better capture the lag structure between SSCM investments and performance payoffs. Second, the sample is confined to formal manufacturing firms registered with industry associations, potentially excluding informal sector enterprises that constitute a significant proportion of Pakistan's manufacturing base. Third, self-reported efficiency and cost competitiveness measures are subject to social desirability bias, despite the psychometric safeguards employed.

Future research should address these limitations through longitudinal designs, multi-informant surveys, and objective financial performance data from audited accounts. Comparative studies across South Asian emerging markets (India, Bangladesh, Sri Lanka) would enable generalisability assessments. Research should also examine the role of digital supply chain technologies—blockchain, IoT-enabled environmental monitoring, AI-driven green procurement analytics—as potential amplifiers of the SSCM-efficiency relationship.

6. Conclusion

This study contributes to the expanding body of knowledge on Sustainable Supply Chain Management by providing rigorous quantitative evidence from Pakistani manufacturing firms on the complex interplay between SSCM practices, firm operational efficiency, and cost competitiveness. Using STATA 17 for OLS regression, mediation, and moderation analyses on a sample of 320 manufacturing firm respondents, the study confirms that green procurement, eco-design, reverse logistics, and environmental collaboration positively influence operational efficiency. However, the trade-off between environmental responsibility and cost competitiveness is empirically substantiated, particularly for green procurement and eco-design.

The partial mediation by Environmental Innovation Capability underscores the critical role of innovation-oriented organisational capabilities in converting SSCM commitments into efficiency dividends. The positive moderation by institutional pressure highlights the enabling role of regulatory and normative environments in amplifying SSCM performance outcomes. Together, these findings suggest that the sustainability-efficiency trade-off, while real, is not immutable: firms that strategically develop environmental capabilities and operate within supportive institutional environments can progressively reconcile environmental responsibility with competitive efficiency.

As global supply chains face intensifying sustainability imperatives from consumers, investors, and regulators, the strategic management of environmental supply chain practices will become an increasingly decisive determinant of long-term firm competitiveness. The challenge for firms in emerging economies like Pakistan is not whether to pursue SSCM but how to do so in ways that leverage institutional support, collaborative relationships, and innovation capabilities to maximise efficiency returns.

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