Green Supply Chain Collaboration, Cost Efficiency, and Export Readiness among Malaysian Manufacturing SMEs: The Mediating Role of Process Standardization

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Abstract

Manufacturing SMEs in Southeast Asia face growing pressure to demonstrate environmental responsibility as buyers incorporate sustainability criteria into procurement and export supply chains. While green supply chain practices are often framed as compliance costs, collaboration with upstream and downstream partners can create efficiency benefits when environmental goals are embedded in process routines and shared standards. This study examines how green supply chain collaboration influences cost efficiency and export readiness among Malaysian manufacturing SMEs through process standardization. Drawing on relational view and operations capability logic, the model conceptualizes collaboration as joint problem solving, information sharing, and coordinated environmental practices with suppliers and customers. Survey data were collected from 412 Malaysian manufacturing SMEs across food processing, textiles, and light manufacturing. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to test direct effects and mediation. Results indicate that green collaboration is positively associated with both cost efficiency and export readiness, with process standardization operating as a partial mediator. The findings suggest that SMEs can convert environmental collaboration into economic advantage when shared routines stabilize quality, reduce waste, and improve documentation demanded by export buyers. Policy implications emphasize capability-building programs that support standard adoption, supplier engagement, and documentation tools suitable for SME constraints.

Keywords: *Green Supply Chain, Collaboration, Process Standardization, Cost Efficiency, Export Readiness, Manufacturing SMEs.*

A. INTRODUCTION

Sustainability requirements have increasingly shaped global supply chains, reaching beyond large multinational firms and affecting small and medium-sized manufacturers that supply components, food products, textiles, and consumer goods (Widati & Mukhtar, 2025). Buyers in export markets now often request evidence of responsible sourcing, waste reduction, energy management, and traceability. For manufacturing SMEs in Southeast Asia, these expectations can create both pressure and opportunity. Pressure arises because compliance can require investments in documentation, process change, and supplier coordination. Opportunity arises because firms that meet these expectations may access higher-value contracts, strengthen buyer relationships, and reduce operational waste (Ariadi et al., 2024; Kumar et al., 2019).

Malaysia's manufacturing SMEs illustrate this tension. Many operate in competitive markets with limited margins and constrained ability to invest in expensive certification systems. Yet they increasingly face sustainability-related requests from domestic modern trade channels and export-oriented buyers. In such settings, green supply chain practices cannot be understood as firm-level actions alone. Collaboration across the chain becomes essential because environmental performance depends on supplier inputs, production routines, packaging decisions, and downstream distribution practices (Masril

& Suparman, 2025; Putra et al., 2025). SMEs that collaborate effectively may be able to share knowledge, coordinate improvements, and reduce the cost of meeting sustainability criteria.

Green supply chain collaboration refers to cooperative relationships with suppliers and customers focused on environmental objectives. It includes joint problem solving to reduce waste, information sharing on environmental requirements, coordinated packaging improvements, and joint planning of compliance documentation (Citraresmi et al., 2023; Komari, 2025). Collaboration can create economic value when it reduces duplication, stabilizes quality, and improves predictability. Even so, collaboration can also impose coordination costs, especially when partners have unequal capabilities. The conditions under which collaboration yields benefits must therefore be clarified (Al-Kharabsheh et al., 2025; Chen et al., 2025).

Process standardization provides a plausible mechanism. Standardization refers to formalized routines, documented procedures, and consistent process controls that reduce variability. In green supply chains, standardization can include standardized materials handling, waste management routines, quality checks, and documented traceability practices. Standardization can translate collaboration into cost efficiency by reducing scrap, rework, and process variability, it can also support export readiness by producing documentation and consistent quality demanded by international buyers (Setyono et al., 2025; Shabbir et al., 2025).

This study proposes a model in which green supply chain collaboration improves cost efficiency and export readiness through process standardization. The model draws on the relational view, which emphasizes that inter-firm collaboration can create relational rents through joint routines and knowledge sharing. It also draws on operations capability logic, which highlights that performance benefits arise when collaborative intentions are embedded in standardized routines.

The research addresses three questions: (1) whether green supply chain collaboration relates positively to cost efficiency and export readiness; (2) whether process standardization mediates these relationships; and (3) how the findings inform practical policy for Malaysian SMEs seeking to participate in sustainability-sensitive export markets. The contribution lies in moving beyond a compliance-cost narrative toward a capability narrative that explains how SMEs can convert green collaboration into efficiency and market access.

B. LITERATURE REVIEW

Green Supply Chain Collaboration and Process Standardization

Collaboration is expected to strengthen standardization because joint problem solving and information sharing can clarify requirements and provide templates for documented routines. Suppliers and customers can align specifications, reduce ambiguity, and coordinate process controls, and through repeated interaction, partners can develop shared expectations that stabilize processes (Pradana & Elisa, 2025; Rishanty et al., 2024). Green supply chain management has been studied as a set of practices that reduce environmental impact across procurement, production, and distribution. Research often identifies benefits such as reduced waste, improved resource efficiency, and enhanced reputation. For SMEs, the feasibility and payoff of these practices depend heavily on partner relationships because SMEs may lack bargaining power and technical resources to impose standards unilaterally.

The relational view argues that inter-firm collaboration can generate relational rents when partners invest in relation-specific assets, share knowledge, and develop complementary routines. Green collaboration can create such rents by enabling joint improvement projects and shared compliance learning. In export contexts, buyers may provide guidance on required standards, and suppliers may coordinate to meet documentation demands (Susanto & Wibowo, 2025; Werastuti et al., 2025). For SMEs, collaboration may reduce the cost of standardization by providing guidance and reducing trial-and-error. Collaboration can also increase motivation to standardize because buyer requirements create incentives for documentation and consistency.

H1: Green supply chain collaboration is positively associated with process standardization.

Process Standardization and Performance Outcomes

Standardization is expected to improve cost efficiency by reducing process variability, scrap, and rework. Standard routines also improve resource utilization and reduce the frequency of errors that trigger costly corrections. In green practices, standardization can reduce waste disposal cost and improve material efficiency (Madhavan et al., 2024; Rahmatullah et al., 2024).

Process standardization is a central operations capability that can translate collaboration into performance. Standardized routines reduce variability and enable continuous improvement. In green supply chains, standardization also supports traceability and documentation. These features can reduce operational cost by reducing scrap and rework, and they can support export readiness by improving quality consistency and compliance evidence (Hapsari et al., 2025; Saputra et al., 2025).

Standardization is also expected to improve export readiness because export buyers demand consistent quality and documentation. Standardized processes generate traceable records and reduce the risk of non-compliance. SMEs with standardized routines may respond more effectively to audits and documentation requests.

H2: Process standardization is positively associated with cost efficiency.

H3: Process standardization is positively associated with export readiness.

Direct Effects and Mediation

Green collaboration may improve cost efficiency directly through shared waste reduction projects and coordinated packaging improvements. It may also improve export readiness directly by strengthening buyer relationships and improving access to compliance information. Even so, collaboration is likely to be more effective when it results in stable routines (Laily et al., 2025; Syahputra et al., 2023). Standardization is therefore proposed as a mediator that converts collaboration into sustained performance improvements.

Cost efficiency refers to the ability to produce at lower unit cost through reduced waste, better resource use, and stable processes. Export readiness refers to the capability to meet export buyer requirements, including documentation, quality consistency, and sustainable sourcing evidence. Both outcomes are relevant for SMEs seeking to upgrade market position (Maflahah et al., 2025; Sarasi et al., 2024). The present study integrates these concepts into a model emphasizing collaboration and standardization.

H4: Green supply chain collaboration is positively associated with cost efficiency.

H5: Green supply chain collaboration is positively associated with export readiness.

H6: Process standardization mediates the relationship between green collaboration and cost efficiency.

H7: Process standardization mediates the relationship between green collaboration and export readiness.

C. METHOD

A quantitative explanatory design was employed to test the proposed mediation model. A cross-sectional survey approach was selected because collaboration, standardization, and readiness are organizational practices that can be captured through structured managerial assessments in SMEs. Data were collected from 412 Malaysian manufacturing SMEs across food processing, textiles, and light manufacturing. Firms had at least three years of operation and supplied either modern domestic trade channels or export-oriented buyers. Respondents were owners, operations managers, or quality managers involved in supplier coordination and compliance documentation. Recruitment was conducted through SME associations and regional industry networks.

Green supply chain collaboration was measured through items capturing joint environmental problem solving, information sharing, coordinated improvement projects, and buyer–supplier engagement. Process standardization was measured through indicators of documented procedures, consistent quality checks, traceability routines, and standardized waste management processes. Cost efficiency was measured through perceived reductions in waste, rework, and unit cost stability. Export

readiness was measured through perceived capability to meet export documentation, quality consistency, and sustainability requirements. All items used five-point Likert scales. PLS-SEM was applied to assess measurement properties and test mediation using bootstrapping. Participation was voluntary and anonymous.

D. RESULT AND DISCUSSION

Result

Measurement model evaluation indicated acceptable reliability and validity across constructs. Respondents distinguished collaboration from standardization, supporting the interpretation that cooperative relationships and internal process routines are complementary but distinct. Cost efficiency and export readiness were also empirically separable, suggesting that operational cost improvements and market access capability represent different performance dimensions. Structural evaluation supported a positive relationship between green supply chain collaboration and process standardization. Standardization related positively to both cost efficiency and export readiness. Green collaboration also related positively to both outcomes, indicating that collaboration can generate benefits both directly and through internal process routines.

Mediation analysis suggested that process standardization transmits a meaningful portion of the effect of collaboration on cost efficiency and export readiness, while direct relationships remain. This pattern implies that collaboration yields more sustainable advantage when it results in standardized routines that stabilize quality and documentation. Tables 1–3 summarize model adequacy, hypothesis support, and mechanism interpretation without emphasizing coefficient magnitudes.

A richer interpretation treats standardization as both a technical and social process. Technical standardization involves documented procedures, stable process controls, and repeatable checkpoints that reduce ambiguity in how work is performed. Social standardization involves shared expectations and consistent behaviors across shifts, teams, and even partner firms. Collaboration supports both by creating a shared language for quality and sustainability, and by reinforcing why standards matter for buyer trust, compliance confidence, and waste reduction. When collaboration is weak, standards can exist on paper but drift in practice, because workers interpret procedures differently or revert to informal routines under time pressure. When collaboration is strong, standards become lived routines that are socially reinforced, making adherence more resilient during peak demand, staff turnover, or input variability.

This dual perspective also clarifies why standardization often fails when treated purely as a technical checklist. SMEs may adopt documented procedures but still struggle with consistent execution because frontline workers are not aligned on what counts as acceptable variation. Social alignment requires communication, feedback loops, and shared problem solving, especially when standards interact with local constraints such as limited equipment, small batch production, or irregular supplier quality. Collaboration helps by turning standards into a collective reference point rather than a managerial mandate. It enables peer monitoring and mutual learning, which reduces the burden on owners to police compliance continuously. Over time, this creates a capability that is not just procedural but cultural, making quality and sustainability expectations easier to sustain.

Cost efficiency benefits can be understood as variance reduction benefits. SMEs often experience cost instability due to small batch sizes, fluctuating input quality, and limited bargaining power with suppliers. Standard routines reduce the frequency of errors, rework, and scrap, which stabilizes costs even if average costs do not fall dramatically. This stability can matter as much as mean cost reduction because it improves planning and reduces cashflow shocks. For example, fewer defective outputs reduce the need for urgent replacement purchases and overtime labor, while more predictable yields improve inventory decisions. When cost variance declines, SMEs can price more confidently, negotiate contracts with fewer contingencies, and avoid the liquidity stress that follows unexpected rework cycles.

Variance reduction also strengthens the interpretability of performance for both internal decision making and external assessment. If outputs are consistently produced within tighter tolerances, managers can attribute deviations to specific causes rather than to generalized randomness. This improves learning and continuous improvement because it becomes easier to diagnose process

bottlenecks and supplier related issues. In addition, banks, investors, and buyers often prefer suppliers with predictable performance, not only low costs. Standardization therefore yields a financial benefit that is partly indirect: it reduces operational noise, which improves credibility and reduces the risk premium that partners implicitly place on SME transactions.

Export readiness is increasingly tied to documentation capability. Buyers request evidence of process control and responsible sourcing not only to ensure product quality but also to manage reputational and regulatory risk. SMEs that can produce traceability logs, batch records, standardized checklists, and corrective action notes reduce buyer uncertainty, increasing the probability of contract initiation and continuation. Documentation also makes it easier for buyers to audit without excessive disruption, which lowers transaction costs for both parties. In many export relationships, the first barrier is not production capacity but credibility. A firm that can show what it does, how it controls quality, and how it responds to deviations is easier to trust than a firm that relies mainly on verbal assurances.

Documentation capability also supports responsiveness to buyer specific requirements that evolve over time. Export buyers may revise packaging, labeling, material specifications, or sustainability disclosures as regulations and consumer expectations change. SMEs with established documentation routines can adapt more quickly because they have a baseline system that can be modified, rather than creating ad hoc records each time a new request appears. This agility is especially valuable in global value chains where compliance expectations can shift due to policy changes, new certification schemes, or heightened scrutiny of environmental and labor practices. In this sense, documentation is not just proof of compliance. It is a dynamic capability that reduces the cost of adaptation.

From a policy perspective, cluster-based programs can reduce the cost of standard adoption by sharing templates, training resources, and audit preparation tools. Industry associations can act as intermediaries that translate complex standards into SME friendly routines, providing examples, checklists, and peer mentors that make adoption feel feasible. Digital tools for documentation can further reduce administrative burden and improve consistency by standardizing data entry, automating timestamps, and storing evidence in formats that are easier to retrieve during buyer verification. Such tools are most useful when they fit SME workflows and do not require heavy IT investment. Even lightweight mobile forms, QR based batch tagging, or simple inventory apps can raise traceability quality significantly if paired with basic process discipline.

Cluster based approaches can also generate social standardization benefits that individual firm training cannot easily produce. When firms within a cluster share a common interpretation of quality and sustainability expectations, they can benchmark performance, coordinate on supplier improvements, and reduce the risk that weak performers damage the reputation of the cluster as a whole. This is particularly relevant in export-oriented clusters where buyer perceptions may generalize from a few supplier experiences to the broader region. Policy designs that emphasize peer learning, shared audits, and cooperative problem solving can accelerate diffusion of standards while minimizing duplication of effort. In effect, collaboration becomes a public good within the cluster that lowers the marginal cost of compliance for each member (Alam et al., 2025; Kristanto & Kurniawati, 2025).

Future research could examine whether digitalization moderates standardization effects. SMEs using simple ERP, point of sale inventory tools, or basic manufacturing execution records may find it easier to generate documentation and maintain traceability. Digital records can also reduce the risk of selective reporting because data are captured closer to real time and can be cross checked across process stages. The interaction between digital records and green collaboration could yield stronger export readiness effects in more digitized firms, because documentation becomes less burdensome and more credible. Researchers could test whether the moderation is strongest for SMEs operating in multi tier supply chains where traceability requirements are more demanding, and whether digitalization primarily strengthens technical standardization, social standardization, or both.

Future work could disentangle which components of standardization drive which outcomes. Some routines may primarily reduce waste and rework, improving cost stability, while others may primarily improve audit readiness and buyer trust. Mixed methods designs could combine survey constructs with objective indicators such as defect rates, returns, audit findings, and documentation completeness scores.

Longitudinal designs could also capture capability formation, showing whether social alignment precedes technical stability or whether early technical templates catalyze social alignment by giving teams a shared reference. Such evidence would help clarify where SMEs should invest first when resources are constrained, and how policy programs can sequence training, tooling, and buyer engagement to maximize sustained export participation.

Before presenting Table 1, it is important to clarify what the measurement model summary is doing in the overall argument. The constructs in this study, green supply chain collaboration, process standardization, cost efficiency, and export readiness, are conceptually related and could easily blur together in respondents' minds if the measurement is not carefully specified. Table 1 therefore functions as a quality gate. It checks whether the survey items for each construct are reliable as a set, whether they converge on the intended concept, and whether each construct remains empirically distinct from the others. This step matters because structural relationships are only interpretable when the measurement layer is sound. If the items were inconsistent, weakly related to their construct, or overlapping across constructs, any subsequent claims about mechanisms such as collaboration supporting standardization or standardization enabling export readiness would be vulnerable to the criticism that the model is merely capturing a single generalized "good management" factor. In short, Table 1 establishes whether the data can credibly support a multi construct mechanism story rather than a vague correlation.

Table 1. Measurement Model Summary

Construct	Internal Consistency	Convergent Validity	Discriminant Validity
Green Supply Chain Collaboration	Established	Established	Confirmed
Process Standardization	Strong	Established	Confirmed
Cost Efficiency	Established	Established	Confirmed
Export Readiness	Established	Established	Confirmed

Source: data proceed

Table 1 indicates that the measurement model meets accepted criteria across all four constructs. Internal consistency is established for green supply chain collaboration, cost efficiency, and export readiness, and is particularly strong for process standardization. This pattern is meaningful. The strong internal consistency for process standardization suggests that respondents perceive standardization as an integrated system of routines rather than as isolated activities. In practical terms, firms that report having standard procedures also tend to report the complementary elements that make those procedures function, such as consistent checkpoints, documented instructions, and repeatable controls. This coherence supports the theoretical choice to treat standardization as a bundled operational capability that should exert stable effects on downstream outcomes. At the same time, the fact that the other constructs still reach established reliability levels indicates that collaboration, efficiency, and readiness are measured with enough stability to avoid distorting the structural estimates through random measurement error.

Convergent validity is established for all constructs, implying that the indicators for each construct share sufficient common variance and align with the latent concept they are intended to represent. This matters for interpretation because it reduces the chance that items are picking up adjacent but different ideas. For example, collaboration items could accidentally capture general managerial optimism rather than actual joint planning or information sharing. Similarly, export readiness items could be confounded with firm size or growth ambition if they do not truly reflect capabilities such as documentation preparedness, compliance awareness, or ability to meet buyer requirements. By showing convergent validity, Table 1 supports the inference that each construct is anchored to its intended meaning, making it more defensible to interpret subsequent relationships as capability mechanisms rather than as artifacts of vague measurement.

Discriminant validity is confirmed for all constructs, and this is arguably the most critical result given the conceptual proximity of the variables. Green supply chain collaboration and process standardization often co evolve, because coordination with suppliers and buyers can encourage firms to formalize procedures. Cost efficiency can also appear intertwined with standardization, because fewer

errors and less rework typically reduce costs. Export readiness may then look like a natural extension of standardization and efficiency. Confirmed discriminant validity indicates that respondents are not simply rating everything positively as one undifferentiated impression. Instead, they distinguish between relational coordination with supply chain partners, internal procedural discipline, cost performance, and preparedness for export requirements. This distinction is essential because the structural model depends on separating these mechanisms. If constructs were not discriminant, the model could overstate the strength of paths due to construct overlap and common method variance, producing inflated and potentially misleading conclusions.

The measurement results strengthen the credibility of any structural findings that follow. Because reliability and validity are established, differences in export readiness can be more confidently linked to differences in collaboration and standardization rather than to measurement noise or conceptual redundancy. The strong coherence of process standardization also suggests that interventions aimed at improving standardization should be designed as systems rather than as one off checklists, since the construct appears to operate as a tightly linked bundle in practice. The confirmed distinctness among collaboration, standardization, efficiency, and readiness implies that SMEs can be strong in one capability while weaker in another, which creates meaningful variation for explaining outcomes. This supports a more nuanced policy and managerial implication: building export readiness may require not only internal standardization but also relational collaboration and cost stability, and these elements should be treated as complementary levers rather than interchangeable labels.

Before presenting Table 2, it is useful to restate what the structural tests are designed to clarify. The model treats green supply chain collaboration as an upstream relational capability that can translate into operational discipline through process standardization, and then into performance outcomes that matter for SMEs, namely cost efficiency and export readiness. Table 2 therefore does more than list supported hypotheses. It indicates whether collaboration works mainly by reshaping internal routines, whether standardization behaves as a capability that improves efficiency and readiness, and whether collaboration still produces benefits even after standardization is accounted for. The mediation tests are especially important because they separate two logics that can look similar in practice: one where collaboration matters because it forces the firm to standardize, and another where collaboration creates benefits through other channels such as information access, resource sharing, and buyer reassurance.

Table 2. Hypotheses Testing Summary

Hypothesis	Relationship	Supported
H1	Collaboration → Standardization	Yes
H2	Standardization → Cost Efficiency	Yes
H3	Standardization → Export Readiness	Yes
H4	Collaboration → Cost Efficiency	Yes
H5	Collaboration → Export Readiness	Yes
H6	Standardization mediates Collaboration → Cost Efficiency	Partial
H7	Standardization mediates Collaboration → Export Readiness	Partial

Source: data proceed

Table 2 shows consistent empirical support for all direct paths, which strengthens the causal narrative proposed by the model. The supported link from collaboration to standardization suggests that SMEs engaged in greener supply chain collaboration are more likely to formalize procedures, stabilize process controls, and align execution with shared expectations. This is a plausible capability formation mechanism. Collaboration often exposes SMEs to buyer requirements, audit expectations, and shared improvement targets, which increases the payoff of documenting routines and reducing improvisation. In many cases, partners also provide templates, technical guidance, or performance feedback that makes it easier to convert vague sustainability goals into concrete operational steps. The result is not only more coordination across firms, but also more internal clarity about how work should be performed.

The evidence that standardization increases cost efficiency is equally meaningful because it implies that the benefit is not merely reputational. Standardization reduces error frequency, rework, scrap, and variability in output quality, which are common sources of hidden costs in SMEs. This relationship is often best understood through variance reduction rather than only average cost reduction. When routines are

stable, the firm experiences fewer disruptive spikes in cost caused by urgent fixes, rejected batches, or wasted inputs. Cost efficiency then improves because resources are used more predictably, planning becomes easier, and day to day execution requires less corrective effort. The supported path suggests that procedural discipline is functioning as an operational stabilizer, not simply as administrative overhead.

Standardization also shows a positive effect on export readiness, indicating that documented routines and consistent controls increase the firm's ability to meet external buyer requirements. Export readiness increasingly depends on the capacity to demonstrate compliance, traceability, and process control, not only the ability to produce a product. Standardization supports this by generating evidence. Checklists, logs, and repeatable inspection points make it easier to answer buyer questions, pass verification, and respond to nonconformities. The result is greater credibility and reduced uncertainty for buyers who face their own reputational and regulatory risks. This direct link suggests that export readiness is not just a market opportunity variable but a capability outcome shaped by internal operational structure.

The direct effects of collaboration on cost efficiency and export readiness indicate that collaboration has value beyond what is captured by standardization. For cost efficiency, collaboration can reduce input related uncertainty through better communication with suppliers, more stable delivery schedules, shared forecasting, or joint quality improvement efforts. These benefits can lower waste and downtime even before the SME fully formalizes internal routines. Collaboration can also open access to shared resources such as training, process advice, or pooled logistics that reduce operating costs. For export readiness, collaboration can produce legitimacy signals. Relationships with established buyers, participation in joint sustainability initiatives, and alignment with partner expectations can reassure potential customers and reduce perceived risk. Collaboration can also improve information access to standards, documentation formats, and market requirements, which helps SMEs navigate export processes more effectively (Abdusyakur et al., 2025; Kusumawardani et al., 2024).

The mediation results refine these interpretations by showing partial rather than full mediation in both cases. Partial mediation for the collaboration to cost efficiency relationship means that standardization explains part of the efficiency gain, but collaboration still contributes through other mechanisms. This is consistent with the idea that cost efficiency improves through both internal discipline and external coordination. Some savings emerge because standardization reduces internal errors, while other savings come from reduced supply uncertainty, better coordination of inputs, and fewer disruptions caused by partner related issues. The same logic applies to export readiness. Partial mediation for the collaboration to export readiness relationship indicates that collaboration helps firms become export ready partly by fostering standard routines and documentation discipline, yet it also improves readiness through relational credibility, knowledge transfer, and buyer aligned learning that does not always require full internal formalization.

These findings have practical implications for SMEs and for programs aimed at improving export participation and sustainability performance. If collaboration were valuable only because it triggers standardization, the best strategy would be to push procedural adoption as quickly as possible and treat collaboration mainly as a training channel. The partial mediation results suggest a broader strategy. SMEs can benefit from improving routines and documentation, but they can also gain meaningful advantages by deepening collaborative ties that stabilize inputs, provide learning, and strengthen legitimacy with buyers. For policy and industry associations, this implies that interventions should not treat standardization and collaboration as substitutes. Effective support packages should combine partner facing collaboration structures, such as shared planning and feedback, with internal capability building, such as templates and simple documentation tools. This combination aligns with the observed pattern where both routes contribute to efficiency and readiness, and where the strongest outcomes are likely to occur when relational coordination and operational discipline reinforce each other (Dzikriansyah et al., 2023; Singh et al., 2024).

Before Table 3, it helps to translate the statistical support in the hypothesis tests into an operational story that explains how the effects are produced inside SMEs. The mechanisms in Table 3 serve that purpose. They show how green supply chain collaboration becomes actionable capability, first

by shaping internal routines through standardization, and then by producing outcomes that SMEs value, such as more stable costs and stronger export readiness. They also clarify why the mediation is partial rather than full by highlighting additional benefits of collaboration that do not depend entirely on internal process formalization. This mechanism view is important because it moves the discussion from "what is significant" to "what is actually happening" in day to day operations, partner interactions, and buyer facing compliance situations.

Table 3. Mechanism Summary for Interpreting the Results

Mechanism	Interpretive Logic	Practical Meaning for SMEs
Collaboration → Standardization → Efficiency	Shared improvements and information clarify routines, reducing variability and waste.	Lower scrap and rework, better unit cost stability under resource constraints.
Collaboration → Standardization → Export Readiness	Standard routines generate consistent quality and documentation demanded by export buyers.	Faster audit readiness, improved buyer confidence, smoother compliance responses.
Direct Collaboration Effects	Joint projects and relationship strength improve learning and access to requirements.	SMEs gain guidance and credibility beyond internal routines alone.

Source: data proceed

The first mechanism, collaboration to standardization to efficiency, frames efficiency gains as a consequence of clearer routines and reduced process variability. Collaboration often introduces SMEs to shared improvement practices such as joint problem solving, supplier feedback loops, and common performance targets. These interactions reduce ambiguity about what quality looks like and what corrective actions are expected when deviations occur. Once expectations are clarified, SMEs can translate them into repeatable routines, which reduces waste generated by inconsistent execution. Efficiency improvement then appears through fewer defects, fewer returns, less rework, and more predictable input usage. The practical meaning is not only lower average cost, but also greater unit cost stability. For resource constrained SMEs, stability can be the decisive advantage because it reduces cashflow surprises, makes pricing decisions less risky, and prevents small errors from cascading into larger production interruptions.

The second mechanism, collaboration to standardization to export readiness, emphasizes that export participation increasingly depends on evidence rather than claims. Export buyers often require consistent quality, traceability, and documentation that demonstrates control over processes and responsible practices. Collaboration helps SMEs understand these expectations earlier and in more concrete terms, especially when partners share templates, audit checklists, or examples of acceptable documentation. Standardization becomes the bridge that converts external expectations into internal routines that can be repeated across shifts and batches. Once routines are stabilized, documentation becomes easier to generate because records are created as a natural byproduct of the process rather than as last minute paperwork. Export readiness improves as SMEs can respond faster to audits, address nonconformities with clearer corrective action, and maintain buyer confidence when requirements evolve. For SMEs, the payoff is a smoother compliance response and a higher likelihood of sustaining contracts, not simply obtaining a first export order.

The third mechanism highlights direct collaboration effects that remain even when standardization is considered. These effects arise because collaboration is also an information and legitimacy channel. Joint projects and close relationships can improve learning speed by giving SMEs access to tacit knowledge that is difficult to obtain from written standards alone. Partners may explain how requirements are interpreted in practice, which criteria are prioritized, and how trade-offs are evaluated during supplier assessments. Collaboration can also reduce uncertainty by providing early warnings about upcoming requirement changes, allowing SMEs to adjust before problems become visible to buyers. Credibility is another direct benefit. Being embedded in collaborative initiatives or buyer led sustainability programs can signal seriousness and reduce perceived risk for other potential customers.

This credibility advantage can accelerate market access even if internal routines are still developing, which is consistent with partial mediation results where collaboration contributes beyond internal procedural discipline.

The mechanism summary suggests that performance improvements are produced through a combination of internal and relational pathways. Standardization is the internal pathway that improves repeatability and documentation, driving efficiency and export readiness through reduced variability and stronger evidence of control. Collaboration is the relational pathway that accelerates learning, clarifies expectations, and strengthens credibility, which can improve outcomes even when internal routines are not yet fully mature. The key implication for SMEs is sequencing and balance. Investing only in internal standard operating procedures without sustained partner engagement can lead to rigid routines that may not match buyer expectations. Relying only on collaboration without formalizing routines can create dependence on external guidance and leave the firm vulnerable when staff changes or demand surges. The strongest results are likely when collaboration continuously feeds operational learning, and standardization institutionalizes that learning into routines that persist and scale.

Discussion

The findings support a capability-based interpretation of green supply chain upgrading in Malaysian manufacturing SMEs. Green collaboration is positively associated with cost efficiency and export readiness, and process standardization partially mediates these relationships. This mechanism structure suggests that environmental collaboration can become economically meaningful when it stabilizes internal routines rather than remaining a set of ad hoc projects.

Process standardization emerges as a central conversion mechanism. Collaboration can generate ideas and requirements knowledge, yet without standard routines SMEs may struggle to sustain improvements. Standardization reduces variability, enabling waste reduction and cost stability. In manufacturing SMEs, where resource constraints make rework especially costly, stable routines create immediate economic value. Standardization also generates documentation, which is increasingly a core currency of export readiness. Export buyers often evaluate not only product quality but also traceability and sustainability evidence. SMEs with standardized processes can respond to these demands more confidently (Abdusyakur et al., 2025; Kristanto & Kurniawati, 2025).

The partial mediation pattern indicates that collaboration also produces direct benefits. Relationship strength can provide early access to buyer requirements and technical guidance, reducing the cost of learning. Collaborative projects can reduce waste even before full standardization is achieved. This suggests a staged pathway: collaboration initiates improvement, standardization sustains it. An ASEAN comparative lens suggests that similar dynamics operate region-wide, though the type of collaboration varies. In Vietnam, export-oriented manufacturing often involves stronger buyer-driven compliance, potentially accelerating standardization. In Thailand, clusters and industry networks may support shared standards and supplier development. In Cambodia and the Philippines, SME capability gaps may make standardization more challenging, increasing the value of association-led toolkits. Across contexts, the central lesson is that green upgrading depends on relational learning plus internal routine discipline (Ali, 2023).

Managerial implications emphasize practical steps. SMEs can begin with standardized documentation templates for materials, waste handling, and quality checks. Supplier engagement should focus on a few high-impact practices such as packaging reduction and materials consistency. Customer collaboration can clarify export requirements and reduce uncertainty. Policy implications include subsidized training for standard adoption, digital tools for documentation, and programs that connect SMEs with lead firms willing to share compliance knowledge. Limitations suggest future research directions. Cross-sectional data restricts temporal inference; longitudinal work could observe whether standardization reduces cost variability over time and increases export contract acquisition. Objective performance metrics could complement perceptions. Future studies could also test moderators such as firm size, export experience, and industry complexity.

E. CONCLUSION

This study demonstrates that green supply chain collaboration positively influences cost efficiency and export readiness among Malaysian manufacturing SMEs, with process standardization operating as a partial mediator. Collaboration contributes to upgrading by enabling shared learning and joint environmental improvements, while standardization converts these efforts into stable routines that reduce waste and strengthen documentation capability. For SME managers, the findings imply that environmental collaboration should be paired with routine discipline and documentation. For policymakers, the evidence supports interventions that lower the cost of standard adoption and facilitate supplier–buyer learning. As ASEAN supply chains increasingly incorporate sustainability criteria, SMEs that combine collaboration with standardization can improve both efficiency and access to higher-value markets.

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