Equilibrium. Quarterly Journal of Economics and Economic Policy
Volume 21 Issue 1 March 2026
p-ISSN 1689-765X, e-ISSN 2353-3293
www.economic-policy.pl

ORIGINAL ARTICLE

Citation: Tedjakusuma, A. P., Kulachai, W., & Rudenko, S. (2026). How green supply chain integration generates sustainable socio-economic value: Economic and eco-innovation effects in manufacturing firms. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *21*(1), 321–371. https://doi.org/10.24136/eq.3983

Contact to corresponding author: Waiphot Kulachai, waiphot.ku@ssru.ac.th

Article history: Received: 19.11.2025; Accepted: 12.03.2026; Published online: 30.03.2026

Adi Prasetyo Tedjakusuma
University of Surabaya, Indonesia
Chaoyang University of Technology, Taiwan
orcid.org/0000-0003-0794-2124

Waiphot Kulachai
Suan Sunandha Rajabhat University, Thailand
orcid.org/0000-0002-3476-9462

Slavomir Rudenko
Pan European University, Slovakia
orcid.org/0009-0008-2438-8974

How green supply chain integration generates sustainable socio-economic value: Economic and eco-innovation effects in manufacturing firms

JEL Classification: *Q55; Q56; O33; L23; M11*

Keywords: *green supply chain management practice; green innovation; socio-economic performance; environmental performance; sustainability value*

Abstract

Research background: Manufacturing sectors in emerging economies face intensifying regulatory, market, and stakeholder pressures to improve environmental stewardship while sustaining competitiveness. Green supply chain management practices (GSCMP) are increasingly

viewed as mechanisms for enabling firms to reduce ecological burdens and create sustainability value. Yet, the mechanisms through which integrated GSCMP translate into sustainable outcomes remain insufficiently specified, particularly in emerging-market manufacturing contexts like Indonesia.
Purpose of the article: This study examines how integrated GSCMP convert into environmental, economic, and social performance by activating two forms of eco-innovation—green process innovation (PCI) and green product innovation (PDI). Building on the practice-based view and normalization process theory, the study tests both direct and innovation-mediated pathways linking GSCMP to sustainability outcomes.
Methods: A survey of 577 Indonesian manufacturing respondents was analyzed using variance-based structural equation modeling. GSCMP were modeled as a second-order formative construct, with PCI and PDI specified as parallel mediators. Direct, indirect, and total effects were assessed through bootstrapping.
Findings & value added: The findings show that integrated GSCMP strongly stimulate both PCI and PDI. PCI is positively associated with sustainable outcomes, whereas PDI is linked to environmental and social outcomes but not to economic gains. GSCMP also exerts effects on all three performance dimensions. The study clarifies that PDI yields more immediate monetizable benefits, while process-oriented greening generates earlier compliance- and legitimacy-based gains. These contributions advance mechanism-level understanding of how GSCMP create sustainability value in emerging-market manufacturing.

Introduction

Manufacturers around the world—in Europe, North America, or the Global South—are under growing pressure to decarbonise their activities without losing competitiveness. Tightening carbon regulations, increasing expectations of CSR by investors and consumers on increased supply chain transparency, and a growing need for consumers to make sustainable purchasing decisions have resulted in supply chain greening shifting from a voluntary initiative to a strategic necessity (Singh *et al.*, 2025; Mohsin *et al.*, 2025). In response, green supply chain management practice (GSCMP) has developed into a holistic strategy requiring companies to align their environmental actions in their purchasing, production, design, and distribution processes, with the aim of reducing their ecological footprints while saving, or enhancing business performance (Wiredu *et al.*, 2024; Zaidi & Lakhal, 2025). Yet despite this global momentum, how GSCMP actually create sustainability value, especially the role of innovation as a transmission channel, is not well understood enough.

Emerging economy manufacturers provide a particularly revealing environment for studying these mechanisms because they both must comply with tightening global standards, and they must deal with weak institutional enforcement and with uneven supplier capabilities. Indonesia is an especially suitable case: its manufacturing sector is a significant source of the country's emissions and is specifically in focus in the country's energy transition roadmaps (International Energy Agency, 2022; Asian Development Bank, 2023). The lessons learned here must thus have a significance far beyond the region.

A growing collection of works connect GSCMP bundles to green innovation and, in turn, to better sustainability performance (Gelmez *et al.*, 2024; Fontoura & Coelho, 2022). Yet key gaps persist. It should be noted that most studies either assume in some way a direct link between GSCMP and performance, or treat green innovation as a single undifferentiated construct. Wiredu *et al.* (2024) studied GSCMP and environmental performance in Chinese manufacturing, but did not separate innovation into process or product streams. Zaidi and Lakhal (2025) concluded that they tested GSCMP against the triple bottom line performance in Tunisia, but did not include innovation in the model at all. Martínez-Falcó *et al.* (2024) included green innovation as a mediator, but it was one variable in a developed economy agri-food environment. Aftab *et al.* (2023) disentangled the mechanism of innovation in Pakistani manufacturing but provided only environmental performance indicators without mentioning economic and social performance. Consequently, we still lack clarity on which innovation channel drives which sustainability dimension, particularly in emerging markets where enforcement is uneven and supplier capabilities vary.

Accordingly, the objective of this study is to examine how integrated GSCMP convert into environmental, economic, and social performance by distinguishing green process innovation (PCI) and green product innovation (PDI) as separate transmission channels in Indonesian manufacturing. Specifically, the study addresses three research questions:

RQ1: *Does integrated GSCMP stimulate both green process innovation and green product innovation?*

RQ2: *Do PCI and PDI differ in how they transmit GSCMP's effects to environmental, economic, and social performance?*

RQ3: *Does GSCMP also influence the triple bottom line directly, beyond the innovation-mediated pathways?*

To answer these questions, the study models GSCMP as a second-order formative capability and tests PCI and PDI as parallel mediators using PLS-SEM on survey data from 577 Indonesian manufacturing firms.

Theoretically, the study draws on the practice-based view (PBV), which posits that widely available routines yield advantage when executed exceptionally well (Bromiley & Rau, 2014), and normalization process theory (NPT), which explains how new practices become embedded and routinized across actors (May & Finch, 2009). By modeling both mediated and direct pathways, we clarify when innovation is the primary conduit from supply-chain greening to sustainability and when end-to-end integration yields additional gains beyond innovation itself.

The value added of this study is fourfold. First, it models GSCMP as a second-order formative capability, capturing its integrative nature. Second, it distinguishes PCI and PDI as parallel mediators, offering fine-grained insight into why some sustainability benefits accrue earlier or more reliably than others. Third, it incorporates the full triple bottom line, including social performance, which is largely underexamined in supply-chain research. Fourth, it provides emerging-market evidence from Indonesian manufacturing, a context with heterogeneous supplier capabilities and uneven institutional enforcement.

The remainder of the article proceeds as follows. Section 2 reviews the relevant literature. Section 3 outlines the methods, measurement model, sampling, and estimation procedures. Section 4 reports the empirical results. Section 5 discusses the theoretical and managerial implications. Section 6 presents the conclusions and directions for future research.

Literature review

Previous studies and gaps identification

Nguyen and Nguyen (2025) tested mediation of green innovation, where internal green HRM and employee involvement improved green product and green process innovation, and these innovations then boosted economic, environmental, and social performance. Their model, however, stayed inside the firm and did not include GSCMP such as green purchasing or green distribution. Li *et al.* (2020) did not use a mediating variable; they linked external pressures and internal–external GSCMP directly to environmental and economic performance and therefore could not show how practices translate into outcomes, and did not test social performance. Gelmez *et al.* (2024) also had no mediator, where GSCMP were related directly to green innovation, environmental performance, and competitive advantage, but innovation was not decomposed. Umar *et al.* (2022) modelled mediation via GSCMP between Industry 4.0 and economic/environmental performance, but they did not analyze green innovation or social performance. Table 1 presents this study's prior studies and gaps.

Taken together, Table 1 reveals three recurring gaps across the prior work. First, most studies either omit a mediating mechanism entirely or treat green innovation as a single undifferentiated variable, making it impossible to tell whether process or product innovation is the active channel. Second, none of the reviewed studies simultaneously covers all three sustainability dimensions: environmental, economic, and social performance within a supply-chain-wide GSCMP framework. Third, emerging-economy manufacturing contexts with formative GSCMP modelling remain underrepresented. The present study is designed to address all three gaps at once.

As such, the present study responds to these limitations by building an explicitly mediating, supply-chain-wide model. It conceptualizes GSCMP as an integrated bundle of practices spanning green purchasing, green manufacturing, green design, and green distribution, and posits that these practices work primarily by activating two innovation capabilities—green process innovation and green product innovation. These mediators then transmit GSCMP's effects to the full set of sustainability outcomes: environmental, economic, and social performance. In doing so, the study links operational practices, innovation mechanisms, and triple-bottom-line results in a single framework, showing not only that GSCMP improve performance, but through which innovation routes that improvement actually occurs.

The Practice-Based View and the Normalization Process Theory

The Practice-Based View (PBV) argues that performance differences often stem from how effectively firms enact widely accessible managerial routines, rather than from possession of rare resources (Bromiley & Rau, 2014). Under PBV, practices such as green purchasing, cleaner production, eco-design, and green distribution are publicly available and imitable; consequently, advantages arise from high-quality implementation across supply-chain activities, not mere adoption (Bromiley & Rau, 2014; Agyabeng-Mensah *et al.*, 2025). Applied to green supply chains, this perspective suggests that environmental and social outcomes diverge because some manufacturers deeply institutionalise GSCMP within purchasing, production, and logistics, whereas others implement them only partially (Zaidi & Lakhal, 2025; Fontoura & Coelho, 2022).

Normalization Process Theory (NPT) complements PBV by specifying how complex practices become routine (May & Finch, 2009). It differentiates four forms of implementation work: coherence (shared sense-making), cognitive participation (enrolment and commitment), collective action (coordinated operationalization), and reflexive monitoring (evaluation and feedback) (May & Finch, 2009). Cognitive participation and coherence in the GSCMP context form a unique identity of new routines and mobilise internal and external actors, for instance, take-back schemes can gain meaning and become distinguishable from prior practices (Wiredu *et al.*, 2024; Gelmez *et al.*, 2024). Subsequent collective action incorporates green routines into existing structures—in many cases PCI and PDI are necessary—and reflexive monitoring examines the sustainable impacts continuously to make further adjustments (Martínez-Falcó *et al.*, 2024). Therefore, greening unfolds as an ongoing, adaptive process rather than a single decision point (May & Finch, 2009).

Bringing PBV and NPT together illuminates the pathway from GSCMP to green innovation and sustainable performance in manufacturing. PBV clarifies why GSCMP can generate sustainability advantages—practices are accessible, but outcomes hinge on implementation quality (Bromiley & Rau, 2014; Agyabeng-Mensah *et al.*, 2025). NPT clarifies how these practices become embedded and why green process and product innovation act as central conduits: as collective action proceeds, misalignments between new routines and legacy technologies trigger cleaner production changes and product redesign; reflexive monitoring then assesses triple-bottom-line effects and steers iterative refinement (May & Finch, 2009; Martínez-Falcó *et al.*, 2024; Zaidi & Lakhal, 2025). Thus, GSCMP adoption supplies the PBV, while NPT's integration work channels that base through innovation to deliver durable environmental gains, competitive efficiency, and social legitimacy (Fontoura & Coelho, 2022; Zaidi & Lakhal, 2025).

The interaction between PBV and NPT works as a sequential, mutually reinforcing mechanism. PBV establishes the what—the portfolio of green practices available to any firm—while NPT explains the how—the embedding work that turns adopted practices into durable, innovation-generating routines. Without a broad practice base to normalise, NPT's mechanisms have nothing to act on; without NPT's coherence and collective action, PBV's accessible routines stay shallow and fail to trigger process or product innovation. The two theories are therefore conditional on each other, the innovation-mediated pathway from GSCMP to performance only activates when practice breadth (PBV) meets embedding depth (NPT). This interaction also implies boundary conditions. Firms with limited absorptive capacity, smaller scale, or weaker interfirm relationships may adopt the same practices but normalise them too shallowly to spark PCI or PDI. High market turbulence or weak enforcement may disrupt reflexive monitoring, slowing the feedback that steers innovation toward triple-bottom-line results. These contingencies help explain why PDI's returns appear robust across contexts while PCI's economic payoff remains maturity-dependent.

Hypothesis development

GSCMP on PCI and PDI

Integrating green purchasing, cleaner production routines, eco-design interfaces, and green distribution reconfigures inter-firm information flows and operating procedures in ways that catalyse process-level change. From a practice-based view, in which widely diffused but well-executed supply chain routines build the organisational capacity for constant improvement (Bromiley & Rau, 2014), the work of embedding new practices—from supplier collaboration to joint problem solving and environmental monitoring —is a recognised precursor to the adoption of pollution prevention and resource-efficient technologies (May & Finch, 2009; Fontoura & Coelho, 2022). When firms coordinate green requirements with upstream and downstream partners, the result is an alignment of both parties to clean up their processes and improve resource efficiency (Feng *et al.*, 2022).

Recent empirical research supports this connection in multiple contexts. Gelmez *et al.* (2024) found that GSCMP directly stimulate green innovation in Turkish manufacturing, while Xiong *et al.* (2025) found that GSCMP promote corporate green innovation in Chinese manufacturing by reducing transaction costs and attracting green investment. Wiredu *et al.* (2024) further established that GSCMP are associated with measurable improvements in the environmental performance of Chinese firms, leading to the implication that changes in processes may be an important underlying mechanism. Together, these findings suggest that GSCMP bundles offer the organisational scaffolding in which process-level greening takes root and scales.

H1: *GSCMP positively influence PCI.*

If environmental requirements are integrated into the sourcing and design touchpoints, firms strengthen the involvement of their suppliers in product development and spread design-for-environment routines. Such upstream engagement expands options for material substitution, dematerialisation, and design-for-recycling, all well-known triggers for product eco-innovation (Feng *et al.*, 2022; Fontoura & Coelho, 2022). Green purchasing collaboration and tighter customer–supplier integration have been found to lead to relatively higher rates of product-level environmental improvements in manufacturing networks (Gelmez *et al.*, 2024; Martínez-Falcó *et al.*, 2024).

Evidence from recent studies reinforces this pattern. Martínez-Falcó *et al.* (2024) found that green innovation mediates the relationship between GSCMP and sustainable performance, indicating that supply chain greening works partly by improving products. Agyabeng-Mensah *et al.* (2025) demonstrated that advanced sustainable practices in supply chains, such as eco-design collaboration, result in better sustainable outcomes at the product level. Xiong *et al.* (2025) also found that GSCMP are positively linked to green innovation in Chinese manufacturing industry partly by reducing transaction costs that would otherwise hinder firms from investing in eco-innovation.

H2: *GSCMP positively influence PDI*.

Green innovation on sustainable performance

The triple bottom line defines sustainable performance in terms of the simultaneous and interrelated pursuit of environmental (ENP), economic (ECP), and social performance (SP) (Elkington & Rowlands, 1999). In manufacturing, GSCMP channel these outcomes through two complementary innovation routes—process and product—which have differing impacts across performance dimensions.

Process-oriented eco-innovations, cleaner technologies, waste and defect reduction, closed-loop recovery, and energy-efficiency improvements, are direct reduction measures that reduce emissions and material intensity, thereby enhancing environmental outcomes. Truong (2025) found, on the basis of firm-level patent and emissions data over a 25-year period, that green process innovations are linked to substantially lower toxic emissions in manufacturing firms. Gelmez *et al.* (2024) also found that green innovation based on GSCM practices leads to improved environmental performance in Turkish manufacturing, confirming that process-level changes are a major channel for generating ecological outcomes.

H3a: *PCI positively influence ENP.*

The economic payoff from process greening comes through productivity gains and lower operating costs. Le and Govindan (2024) showed, in a PLS-SEM study of Vietnamese SMEs, that green process innovation significantly improves corporate performance, as cleaner processes cut resource waste and streamline operations. Fontoura and Coelho (2022) reinforced this by demonstrating that supply chain collaboration oriented toward process improvement translates into tangible performance gains, though such benefits tend to be optimal when firms possess complementary inter-firm capabilities that allow them to capture efficiency rents.

H3b: *PCI positively influence ECP*.

At the social level, safer and cleaner operations make workplaces healthier, reduce harmful externalities for surrounding communities, and build stakeholder legitimacy. Zaidi and Lakhal (2025) tested GSCMP's effects on all three performance dimensions in Tunisian manufacturing and found that greener practices, which operate partly through process improvements, contribute positively to social performance indicators. Agyabeng-Mensah *et al.* (2025) extended this logic by showing that well-implemented sustainable supply chain practices strengthen community-focused and employee-focused performance outcomes in manufacturing.

H3c: *PCI positively influence SP.*

Product-focused eco-innovations (e.g., material substitution, design for recycling, low-toxicity formulations, eco-packaging) are used to reduce environmental impacts over the product life cycle. Truong (2025) showed that green product innovations are associated with lower firm-level emissions, as redesigned products require fewer polluting inputs across their life cycle. Martínez-Falcó *et al.* (2024) confirmed that green innovation, including product-level changes, mediates the link between GSCMP and ENP in manufacturing companies.

H4a: *PDI positively influence ENP*.

From an economic perspective, increased greenness of products brings differentiating advantages, quality premiums, and access to regulation-insulated market niches. Le and Govindan (2024) found green product innovation to have a significant impact on the financial performance of manufacturing SMEs, as eco-designed products attract environmentally oriented customers and command higher margins. Gelmez *et al.* (2024) found that green innovation is associated with competitive advantage in manufacturing, suggesting that product-level improvements support market differentiation.

H4b: *PDI positively influence ECP*.

At the social level, greener products reduce health and safety hazards for end users and communities while meeting stakeholder expectations, thereby improving corporate reputation. Zaidi and Lakhal (2025) showed that GSCMP, including product-level greening, positively influence social performance in manufacturing. Agyabeng-Mensah *et al.* (2025) also found that advanced sustainable supply chain practices, such as eco-design collaboration at the product level, build social outcomes such as community relations and employee satisfaction.

H4c: *PDI positively influence SP.*

GSCMP on sustainable performance

When green routines are ingrained and widespread in sourcing, production, design, and distribution, companies tend to have a lighter ecological footprint. Under PBV, it is not adoption but the consistency and depth of implementation that determine whether environmental gains materialise (Bromiley & Rau, 2014). Firms that organise green purchasing, cleaner production, eco-design, and green logistics across the supply chain target emissions, waste, and resource consumption at multiple operational points simultaneously.

Empirical evidence supports this reasoning. Wiredu *et al.* (2024) found that the use of GSCMP improved ENP among manufacturing firms in China in terms of emissions and resource efficiency by a significant margin. Gelmez *et al.* (2024) demonstrated a similar direct relationship in Turkish manufacturing, showing that firms coordinating green activities throughout the supply chain achieve measurably better ecological outcomes.

H5a: *GSCMP positively influence ENP*.

Whether greening makes economic sense is a subject of debate, particularly since near-term compliance expenditures and capital expenditures can eat into margins. On the contrary, PBV argues that widely available green routines, such as purchasing, eco-design, cleaner logistics, create economic benefits when implemented with breadth and fidelity across the supply network, which reduce material, energy, and disposal costs and streamline operations (Bromiley & Rau, 2014).

Recent work confirms this logic. Agyabeng-Mensah *et al.* (2025) provided evidence that well-implemented GSCMP improve ECP in manufacturing by reducing operating costs across the chain. Fontoura and Coelho (2022) reinforced this by showing that collaboration-driven green innovation within the supply chain translates into tangible financial gains, particularly when firms develop complementary inter-firm capabilities.

H5b: *GSCMP positively influence ECP*.

Supply chain greening is also a boost for the social pillar: corporate image, employee satisfaction, and community commitment. When it is visible that firms are taking environmental practices seriously and partner organisations are also required to do so, they signal to stakeholders that they are responsible, building a sense of trust and social legitimacy that is not confined to factory walls.

This link has found support in recent studies. Zaidi and Lakhal (2025) tested GSCMP's effect on all three performance dimensions in Tunisian manufacturing and found that greener supply chain practices contribute positively to social performance indicators. Agyabeng-Mensah *et al.* (2025) extended this by showing that advanced sustainable supply chain practices strengthen both community-focused and employee-focused outcomes in manufacturing settings.

H5c: *GSCMP positively influence SP*.

Green innovation as a mediator between GSCMP and sustainable performance

The study posits that GSCMP influence sustainable performance not only directly (H5a–c) but also indirectly through two parallel innovation channels: green process innovation (PCI, H6a–c) and green product innovation (PDI, H7a–c). Each mediation pathway is developed below.

Extending a practice-based account of how supply chains create value, we argue that GSCMP operate through process-innovation capabilities to affect sustainability outcomes. GSCMP diffuse environmental objectives upstream and downstream and restructure operating routines, which catalyse process-level changes—emissions reduction, waste recycling, material minimisation, and energy-efficiency upgrades (Xiong *et al.*, 2025; Gelmez *et al.*, 2024). These process innovations then serve as the transmission channel through which greening reaches all three performance dimensions.

Evidence supports this mediation logic across each dimension. For environmental performance, Truong (2025) confirmed, using 25 years of patent and emissions data, that firms with more green process patents produce measurably lower toxic emissions. For economic performance, Le and Govindan (2024) demonstrated that green process innovation significantly improves corporate financial outcomes among Vietnamese manufacturing SMEs by cutting resource waste and streamlining operations. For social performance, Zaidi and Lakhal (2025) found that greener supply chain practices contribute positively to social outcomes, while Agyabeng-Mensah *et al.* (2025) showed that well-implemented sustainable practices strengthen employee- and community-focused results.

H6a: *PCI mediates the GSCMP–ENP relationship.*

H6b: *PCI mediates the GSCMP–ECP relationship.*

H6c: *PCI mediates the GSCMP–SP relationship*.

By cascading environmental requirements to suppliers and integrating eco-criteria into design and distribution, GSCMP foster product-level innovations, material substitution, design-for-recycling, low-toxicity formulations, and eco-packaging. These product improvements then act as the conduit through which GSCMP's influence reaches ENP, ECP, and SP, because they alter what firms offer to markets, regulators, and communities rather than only how they produce.

Recent evidence supports this mediation pathway across each dimension. For ENP, Truong (2025) found that green product innovations are associated with lower firm-level emissions, as redesigned products require fewer polluting inputs across their life cycle, and Martínez-Falcó *et al.* (2024) confirmed that green innovation mediates the GSCMP–ENP link. For ECP, Le and Govindan (2024) demonstrated that green product innovation enhances corporate financial outcomes as eco-designed products attract environmentally conscious buyers and command higher margins, while Gelmez *et al.* (2024) found that green innovation is linked to competitive advantage in manufacturing. For SP, Zaidi and Lakhal (2025) showed that GSCMP positively affect SP, and Agyabeng-Mensah *et al.* (2025) found that advanced sustainable supply chain practices, including eco-design collaboration, strengthen community relations and employee satisfaction.

H7a: *PDI mediates the GSCMP–ENP relationship*.

H7b: *PDI mediates the GSCMP–ECP relationship.*

H7c: *PDI mediates the GSCMP–SP relationship.*

All the developed hypotheses are shown in Figure 1.

Empirical challenges and methodological considerations

The reviewed studies reveal several recurring limitations. First, most treat GSCMP as a first-order reflective construct, which lumps purchasing, manufacturing, design, and distribution practices into a single score, making it difficult to see which bundles of practices truly drive performance (Wiredu *et al.*, 2024; Gelmez *et al.*, 2024). Second, almost all rely on single-informant cross-sectional surveys, a design vulnerable to common method variance, which is often acknowledged but not always adequately tested (Zaidi & Lakhal, 2025; Agyabeng-Mensah *et al.*, 2025).

Third, when innovation is included at all, it is frequently treated as an undifferentiated construct, making it unclear whether efficiency gains stem from process improvements or product redesign (Martínez-Falcó *et al.*, 2024; Le & Govindan, 2024). Finally, emerging-economy contexts beyond China remain underrepresented, limiting insight into settings where enforcement is uneven and supplier capabilities vary widely (Fontoura & Coelho, 2022; Xiong *et al.*, 2025). The analytical platform, PLS-SEM with 5,000-resample bootstrapping, fits both the formative specification of GSCMP and the model's complexity. Together, these methodological choices address common weaknesses in the literature and lay the groundwork for the subsequent methods section.

Methods

Operationalization and measures

This study draws a clear conceptual distinction between two forms of green innovation that serve as parallel mediators. Green process innovation (PCI) refers to the adoption or development of new or significantly improved manufacturing processes, technologies, and operational procedures aimed at reducing environmental impacts, encompassing pollution prevention, hazardous emission reduction, waste recycling, energy and water conservation, and raw material minimization within the firm's production system (Begum *et al.*, 2022; Xie *et al.*, 2022). Green product innovation (PDI) refers to the development or modification of products to reduce their environmental burden across the product life cycle, including the use of non-toxic or reduced-toxicity materials, incorporation of recyclable and biodegradable inputs, recovery of end-of-life products, and adoption of eco-labeling (Negi *et al.*, 2023; Feng *et al.*, 2022). These definitions are rooted in the environmental innovation literature in supply chain and operations management (Truong, 2025; Le & Govindan, 2024) and are broadly consistent with the process/product innovation distinction established in mainstream innovation scholarship, while being specifically tailored to the environmental manufacturing context. Importantly, the two constructs are conceptually distinct: PCI targets how a firm produces, its internal transformation processes, whereas PDI targets what a firm produces, the environmental attributes of its outputs. This distinction is preserved across the operationalization, measurement items, and structural model specification.

The study defines three constructs: GSCMP, green innovation (process, product), and sustainable performance (environmental, economic, and social). All indicators use a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree). Following prior work that treats GSCMP as an integrated capability, GSCMP is modeled as a second-order formative construct composed of four first-order reflective dimensions: green purchasing, green manufacturing, green design, and green distribution. Full operationalizations and items are reported in Table 3.

Sampling technique and data collection

The target population was Indonesian manufacturing firms with an established organizational structure (≥ 30 employees). To obtain informed, firm-level responses, we surveyed key informants by rank, supervisors and higher authorities (managers, senior managers, department heads, directors/vice-presidents, owner-executives). The unit of analysis is the firm.

The sampling frame was assembled through the Indonesian Employers Association network and the University of Surabaya's Industrial Partnership Unit, leveraging colleagues and close industry contacts (the author is an Indonesian employer and a partnership unit member). This frame was supplemented with association rosters, university, and professional referrals. A purposive sampling approach was used, with eligibility screens requiring a manufacturing firm, full-time employment, and ≥ 1 year of employment in a supervisory or higher role. The survey online was conducted over an eight-month period between October 2024 and May 2025. Invitation email messages with a secure link were sent to 1,150 potential respondents, followed by WhatsApp messages and phone calls. In total, 950 invitees opened or started the questionnaire and 610 completed all sections; after eliminating cases of inattention or partial completion, 577 usable responses were obtained, yielding a usable response rate of 32.4% (577/1,150). Participation was voluntary and confidential, informed consent was obtained, and results are reported only in aggregate.

Because the study relies on purposive (non-probability) sampling, five safeguards were implemented to enhance the credibility and analytical generalizability of the results. First, eligibility screening was applied rigorously, with inclusion limited to respondents from manufacturing firms with ≥ 30 employees who were in full-time employment and held supervisory or higher job positions with ≥ 1 year of tenure. This ensured informant competence, which is of paramount concern in organizational-level survey research. Second, the use of multi-channel sampling frames reduced reliance on any single network. The frame drew from three distinct sources—the Indonesian Employers Association roster, the University of Surabaya's Industrial Partnership Unit, and professional referrals—thereby reducing self-selection bias associated with single-gateway recruitment. Third, demographic heterogeneity was confirmed post hoc. The final sample covered a broad range of firm sizes (30 to > 1,000 employees), industry subsectors, managerial ranks (from supervisors to owner-executives), tenure lengths, and education levels, indicating meaningful variation rather than representation of a narrow segment. Fourth, statistical remedies were applied. Common method variance was evaluated, and PLS-SEM bootstrapping (5,000 resamples) is robust for inference without assumptions about distributional shape, partially mitigating non-probability sampling limitations. Fifth, the large effective sample size (n = 577) from 1,150 invitations—with a 50.2% usable response rate among those who started the questionnaire—reduces practical concerns related to self-selection bias; higher participation and sample diversity enhance the reliability of observed relationships across firms' characteristics.

Survey instrument and data-quality protocols

The online questionnaire was built on a secure, HTTPS-encrypted survey platform hosted through a university-affiliated account. Invitation emails containing the survey link were sent to 1,150 potential respondents, followed by WhatsApp reminders and phone calls to non-respondents over the eight-month data collection period. The questionnaire did not capture any personally identifiable information such as names or email addresses. A separate internal tracking file matched invitation records with response status solely for follow-up purposes and was permanently deleted after data collection. The final dataset was stored on a password-protected institutional cloud drive accessible only to the research team.

The total instrument comprised 43 items. Six opening items captured demographic and firmographic profiles on a categorical basis (gender, age group, education level, firm size, managerial position, and tenure length). The remaining 34 items were substantive measurement statements rated on a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree), operationalizing nine constructs (four GSCMP dimensions—green purchasing, green manufacturing, green design, green distribution; two types of green innovation—process and product; and three dimensions of sustainable performance—environmental, economic, and social). Complete item wordings are presented in Table 3. Two attention-check items were embedded at approximately the one-third and two-thirds points of the questionnaire (e.g., "For quality assurance purposes, please select 'Agree' for this item").

These checks, alongside completion-time analysis and straight-lining detection, served as data-quality screens. Of the 610 completed submissions, 33 were flagged and removed due to failed attention checks, invariant response patterns across consecutive item blocks, or abnormally short completion times (below the 5th percentile of the distribution), resulting in the 577 usable responses reported above. The full research instrument, including demographic items, attention checks, and complete Likert response format, is provided in Appendix B.

The minimum required sample size was assessed through two complementary approaches. Under the ten-times rule commonly applied in PLS-SEM (Hair *et al.*, 2017), the threshold equals ten times the larger of (a) the maximum number of formative indicators for any single construct or (b) the maximum number of structural paths directed at any endogenous construct. In the model, GSCMP has four formative indicators, and each performance construct has three incoming paths; thus, the binding constraint is $4 \times 10 = 40$ observations. As a second check, an a priori power analysis was conducted in G*Power 3.1 (Faul *et al.*, 2009) for linear multiple regression with three predictors, a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, and statistical power of 0.80, yielding a minimum requirement of 77 cases. The achieved sample size of 577 comfortably exceeds both thresholds, indicating sufficient statistical power.

A structured questionnaire was selected as the research tool because the constructs under study, green supply chain practices, innovation orientations, and perceived performance outcomes, are latent, perceptual, and largely internal to the firm. In Indonesian manufacturing, where standardized environmental reporting remains limited, these phenomena are not readily captured through secondary or archival data (Wiredu *et al.*, 2024). Self-administered survey instruments built on validated scales are the established approach in GSCMP research (Zaidi & Lakhal, 2025; Martínez-Falcó *et al.*, 2024) and in PLS-SEM-based organizational studies more broadly (Hair *et al.*, 2017). The geographical spread of manufacturing firms across the Indonesian archipelago further favoured an online format as the most scalable and cost-effective data collection method.

The opening page of the questionnaire provided a written informed consent statement. It explained the academic purpose of the study, affirmed that participation was entirely voluntary and anonymous, stated that the data would be used only for scientific research, and explained that respondents could withdraw at any point without consequence. Participants were required to check an “I agree to participate” checkbox before the first survey page was loaded. This procedure was carried out in accordance with the principles of the Declaration of Helsinki for research involving human subjects.

The instrument was pretested in two rounds before deployment. In the first round, the questionnaire was reviewed for content validity, clarity, and contextual appropriateness for the Indonesian manufacturing setting by three academic experts in supply chain management and two industry practitioners. Their feedback resulted in refinement of some item wordings and the rewriting of one item that was judged to be ambiguous. In the second round, conducted as a pilot study, 30 respondents were selected from the target population. Item-level statistics (means, standard deviations, item-total correlations) and Cronbach’s alpha (CA) values were examined to assess internal consistency; only a few items were removed at this stage. The questionnaire was originally prepared in English and translated into Bahasa Indonesia using a back-translation procedure to ensure semantic equivalence.

Analysis technique

Structural equation modelling (SEM) was used to test the reflective measurement specifications and the hypothesized causal relationships in the framework, with all analyses conducted using SmartPLS 4.1.1.2. The variance-based PLS-SEM approach was appropriate because the model comprises multiple latent variables connected through mediating paths and, although theory-driven, aims to refine and extend understanding of sustainability-related linkages (Hair *et al.*, 2017). As the dataset was collected through a single self-report survey, the analysis began with an assessment of common method variance (CMV), the full results of which are reported in the Model Robustness Testing subsection.

The outer model was assessed before interpreting the structural results. Convergent validity was supported by retaining indicators with outer loadings of at least 0.70 and by confirming average variance extracted (AVE) values of ≥ 0.50 for each construct, indicating sufficient shared variance between constructs and their measures (Baumgartner & Weijters, 2021). Reliability was evaluated using CA and composite reliability (CR), both of which exceeded the recommended threshold of 0.70, demonstrating internal consistency (Hair *et al.*, 2017). Discriminant validity was examined using the Fornell–Larcker criterion and cross-loadings to ensure constructs were empirically distinct and that indicators loaded most strongly on their intended variables (Henseler *et al.*, 2015). Once these conditions were met, the inner model was evaluated using R^2 values for endogenous constructs.

Second-Order Construct Specification and Estimation (Two-Stage PLS-SEM)

This study models GSCMP as a second-order formative construct composed of four reflective first-order dimensions—green purchasing, green manufacturing, green design, and green distribution. Conceptually, firms tend to adopt these practices as a mutually reinforcing bundle that collectively signals an overarching green supply chain orientation, rather than as a set of isolated operational routines. Estimating GSCMP hierarchically captures this integrative capability while avoiding indicator proliferation and collinearity issues that may arise when first- and higher-order indicators are estimated simultaneously (Sarstedt *et al.*, 2019; Hair *et al.*, 2022).

Stage 1 (Measurement of Lower-Order Components)

We first estimated a model containing the four reflective GSCMP dimensions alongside the other reflective constructs (PDI, PCI, and the three performance outcomes). Each first-order GSCMP construct was evaluated for indicator loadings, internal consistency (CA and CR), convergent validity (AVE ≥ 0.50), and discriminant validity (Fornell–Larcker criterion and cross-loadings). After confirming measurement quality, latent variable (LV) scores for the four GSCMP dimensions were exported from SmartPLS 4.1.1.2. These scores represent respondents' standardized positions on each dimension and served as empirically derived indicators of the higher-order construct.

Stage 2 (Higher-Order Construct and Structural Testing)

The four Stage 1 LV scores were then re-imported as manifest indicators of a single formative GSCMP construct. The structural model specified paths from GSCMP to PCI and PDI, followed by paths from process/product innovation to ENP, ECP, and SP. To adjudicate partial versus full mediation, direct paths from GSCMP to each performance construct were also included. Statistical inference for all direct and specific indirect effects was conducted using bootstrapping with 5,000 resamples.

Results

Sample demographics

This study examined 577 participants from Indonesian manufacturing firms. Males dominated the respondent pool (66.90%), which corresponds to a production-intensive context. Participants were predominantly in the mid-career age groups of 30–39 years (37.95%) and 40–49 years (32.58%), indicating sufficient organizational experience to evaluate green practices. Educational attainment was high, with Master's (48.35%) and Bachelor's (34.84%) degrees predominating, implying a largely tertiary-educated cohort capable of interpreting firm-level processes. Current positions were dominated by managers (45.23%) and supervisors (36.05%), while senior leadership (general managers, directors, and owners; approximately 18%)

provided strategic perspectives. Tenure duration was concentrated in the 5–7 year range (35.36%) and the 2–4 year range (28.77%), indicating experienced role holders. Firm size was skewed toward medium enterprises, with 100–1,000 employees (30.68%) and 51–100 employees (25.13%). Overall, the sample comprises well-educated, middle-aged decision-makers appropriate for evaluating GSCMP, innovation, and sustainable performance. Complete sample demographics are presented in Table 2.

Firm sizes were classified according to employee numbers, following the categorization applied by Indonesia's Central Statistics Agency (BPS, 2023) in its annual Large and Medium Industry Survey, in which manufacturing enterprises with 20 or more employees qualify as medium-to-large firms. This range was divided into five brackets (30–50, 51–100, 100–1,000, 1,001–5,000, and ≥ 5,001 employees) to better capture size-related differences, in a manner consistent with the Enterprise Surveys conducted by the World Bank for Indonesia (World Bank, 2023).

Validity and reliability assessment

The measurement model was evaluated in SmartPLS 4.1.1.2 to ensure that the data met established reliability and validity standards before interpreting the structural relationships. Indicator reliability was first examined through outer loadings. All items exceeded the recommended threshold of 0.70, indicating that each indicator contributes reliably to its respective construct and that the constructs are well represented by their measurement items (Hair *et al.*, 2017). Convergent validity was assessed using AVE values. All constructs exhibited AVE values greater than 0.50, demonstrating that each latent variable explains more than half of the variance in its indicators and thus captures its intended domain effectively (Hair *et al.*, 2017). Internal consistency reliability was further confirmed through CA and CR, both of which exceeded 0.70 across all constructs. Collectively, these results indicate a high-quality and reliable measurement model suitable for subsequent structural testing (Table 4).

Social performance (SP) exhibited the lowest AVE among the constructs (0.567), which remains above the 0.50 threshold, indicating that the construct explains more than half of the variance in its indicators (Hair *et al.*, 2017). All four SP indicators loaded above 0.70 (0.731–0.771), and both CA (0.747) and CR (0.750) exceeded the recommended benchmark. The slightly lower AVE is unsurprising given that social performance is a broad construct encompassing corporate image, employee welfare, community relations, and stakeholder trust. Comparable AVE levels for similar constructs have been reported as acceptable in recent GSCMP research when indicator loadings and reliability are otherwise satisfactory (Wiredu *et al.*, 2024; Zaidi & Lakhal, 2025). It is important to note that PLS-SEM evaluates measurement quality using outer loadings, AVE, CR, and discriminant validity measures (Fornell–Larcker criterion, Heterotrait–Monotrait ratio [HTMT], and cross-loadings), rather than exploratory factor analysis (EFA) procedures such as eigenvalue extraction, total variance explained, or factor rotation. These EFA-based criteria apply to covariance-based SEM but are not part of the PLS-SEM assessment protocol, where constructs are modeled as weighted composites (Hair *et al.*, 2017). The criteria reported in Tables 4–7 collectively confirm satisfactory measurement quality for all constructs, including SP.

After establishing convergent validity and internal consistency, discriminant validity was tested using three complementary approaches. First, the Fornell–Larcker criterion verified that the square root of each construct's AVE was higher than its correlations with other constructs, supporting adequate separation among latent variables (Table 5). Second, cross-loading analysis showed that each indicator loaded most strongly on its assigned construct relative to others, reinforcing the distinctiveness of the measurement items (Table 7). Third, the HTMT ratio was evaluated using the conservative 0.85 cutoff recommended by Henseler *et al.* (2015). Nearly all HTMT values fell below this threshold, providing strong evidence that the constructs measure conceptually different phenomena (Table 6). Taken together, these checks confirm that the measurement model demonstrates satisfactory reliability, convergent validity, and discriminant validity.

Model robustness testing

The structural model was first evaluated for explanatory power. Using Falk and Miller's (1992) criterion that R^2 should be > 0.10, all endogenous constructs met the minimum requirement. Explanatory strength was substantial for green innovation, with $R^2 = 0.642$ for PCI and $R^2 = 0.606$ for PDI, indicating that GSCMP is a strong driver of both innovation types. The sustainability outcomes were also meaningfully explained: ENP ($R^2 = 0.517$), ECP ($R^2 = 0.406$), and SP ($R^2 = 0.437$). Overall, these R^2 values indicate that the model captures considerable variance in innovation and performance outcomes.

Because all data were collected from a single self-report survey, several steps were taken to address common method variance (CMV). Procedurally, three safeguards were incorporated into the data collection: respondent anonymity was guaranteed with no personally identifiable information collected; scale items for independent and dependent constructs were placed in separate questionnaire sections to limit respondents' ability to infer expected relationships; and two attention-check items screened for careless responses. Statistically, Kock's (2015) full collinearity approach was applied—if all variance inflation factor (VIF) values fall at or below 3.3, the model can be considered free of common method bias. All outer VIF values ranged from 1.303 to 2.317, and all inner VIF values peaked at 3.281, both below the threshold, indicating that CMV does not threaten the validity of the structural estimates.

Multicollinearity was checked at two levels using SmartPLS 4.1.1.2. For the outer (indicator-level) model, all VIF values ranged from 1.303 to 2.317, well below the conservative cutoff of 3.3 (Kock, 2015). For the inner (structural) model, VIF values for predictor sets reaching each endogenous construct peaked at 3.281, again comfortably under the threshold. These results rule out multicollinearity as a threat to the estimated path coefficients.

Model fit was then assessed to evaluate alignment between the estimated model and the observed data. Following Hu and Bentler (1999), the standardized root mean square residual (SRMR) was used as the primary absolute fit index. The SRMR value of 0.074 falls below the ≤ 0.08 threshold, suggesting acceptable residual differences between reproduced and observed correlations. Bootstrapping-based fit measures further supported this conclusion (d_ULS = 3.232; d_G = 1.029; NFI = 0.700). Although NFI is typically interpreted more conservatively in covariance-based SEM, in PLS-SEM it is considered alongside SRMR and R^2 values, given the method's predictive orientation. Overall, these results indicate a well-specified and empirically robust model that explains how GSCMP drive green innovation and sustainability performance.

Hypothesis testing

Direct effect hypotheses

H1 and H2 highlight the central role of GSCMP. Firms that adopt green purchasing, green production, green design, and green distribution report a very strong increase in PCI (H1: $\beta = 0.799$, T = 45.483) and a similarly strong increase in PDI (H2: $\beta = 0.778$, T = 35.442). Results for innovation–performance linkages are partly differentiated. PCI is positively associated with ENP (H3a: $\beta = 0.201$, T = 2.711) and also improves SP (H3c: $\beta = 0.134$, T = 2.001). However, the PCI → ECP path is not significant (H3b: $\beta = -0.074$, T = 0.940). Introducing green products improves ENP (H4a: $\beta = 0.332$, T = 4.872), ECP (H4b: $\beta = 0.430$, T = 5.816), and SP (H4c: $\beta = 0.231$, T = 3.631). The final set of hypotheses (H5a–H5c) demonstrates that GSCMP also exert direct effects. GSCMP are positively associated with ENP ($\beta = 0.257$, T = 3.711), ECP ($\beta = 0.337$, T = 4.688), and SP ($\beta = 0.377$, T = 5.981). All direct hypothesis testing results are reported in Table 8 and illustrated in Figure 2.

Indirect effect hypotheses

The first mediation pathway through PCI is partially supported. GSCMP → PCI → ENP is significant (H6a: $\beta = 0.161$, T = 2.680), as is GSCMP → PCI → SP (H6c: $\beta = 0.107$, T = 1.978). However, GSCMP → PCI → ECP is not significant (H6b: $\beta = -0.059$, T = 0.940). The second mediation pathway through PDI is fully supported and exhibits stronger effects. GSCMP → PDI → ENP (H7a: $\beta = 0.258$, T = 4.697), GSCMP → PDI → ECP (H7b: $\beta = 0.335$, T = 6.018), and GSCMP → PDI → SP (H7c: $\beta = 0.180$, T = 3.538) are all significant. Indirect hypothesis testing results are presented in Table 9 and Figure 2.

Discussion

GSCMP as a driver of dual green innovation (H1–H2)

H1 and H2 show that integrated GSCMP are positively and strongly associated with both PCI and PDI. When environmental goals are woven across purchasing, manufacturing, and distribution, firms gain both the pressure and the capability to redesign processes and products. This holds across geographies: Xiong *et al.* (2025) found the GSCMP–innovation link in China, Fontoura and Coelho (2022) in European supply chains, Martínez-Falcó *et al.* (2024) in Spanish agri-food manufacturing, and Gelmez *et al.* (2024) in Turkey. This cross-continental consistency points to a general organisational mechanism—one that the PBV would predict, since broadly available routines generate advantage through execution quality rather than rarity (Bromiley & Rau, 2014). NPT adds an explanation of how this occurs: coherence and collective action embed green criteria into daily operations, creating conditions under which process redesign and product-level eco-innovation naturally emerge (May & Finch, 2009).

Process innovation pathways to the Triple Bottom Line (H3a–c)

PCI is positively associated with ENP (H3a) and SP (H3c), but not with ECP (H3b). Truong (2025) confirmed the PCI–ENP relationship using 25 years of global patent data, and Čater *et al.* (2025) showed that green process innovation acts as a distinct sustainability pathway in European manufacturing. The social dividend—cleaner workplaces and fewer community externalities—is similarly cross-regional, with supporting evidence from Tunisia (Zaidi & Lakhal, 2025) and Ghana (Agyabeng-Mensah *et al.*, 2025).

The nonsignificant PCI–ECP path is one of the most theoretically revealing results. It contrasts with Le and Govindan (2024), who found a positive relationship in Vietnamese SMEs, and with Fontoura and Coelho (2022), who noted that financial returns depend on complementary inter-firm capabilities. However, this finding aligns with a broader stream of research suggesting that the economic payoff from process greening is not straightforward. Xie *et al.* (2022) uncovered a U-shaped pattern in which financial performance declines in the early stages of green process adoption and recovers only after a critical implementation threshold is crossed—the payoff is delayed rather than absent. Ai *et al.* (2024) confirmed this nonlinear dynamic and further demonstrated that high financial leverage amplifies early-stage cost burdens. Appiah *et al.* (2025) add that process innovation translates into financial returns only when paired with green value co-creation and customer-oriented strategies; without these complementary conditions, economic gains remain elusive.

Through the PBV × NPT lens, these findings are coherent. Process greening requires deep normalisation before efficiency gains materialise. Implementation maturity thus emerges as a key boundary condition, suggesting that firm size, resource depth, and strategic partner alignment (Appiah *et al.*, 2025; Fontoura & Coelho, 2022) moderate how quickly the PCI–ECP relationship turns positive.

Product innovation pathways to the Triple Bottom Line (H4a–c)

PDI is positively associated with all three performance dimensions—ENP (H4a), ECP (H4b), and SP (H4c)—making it the more complete transmission channel. Truong (2025) and Čater *et al.* (2025) confirmed the PDI–environmental relationship globally and in Europe, respectively. Economic returns are supported by evidence from Vietnam (Le & Govindan, 2024), Ghana (Appiah & Essuman, 2024), and Latin America (Morán *et al.*, 2025), while social gains are observed in Tunisia (Zaidi & Lakhal, 2025) and Ghana (Agyabeng-Mensah *et al.*, 2025).

Theoretically, PBV × NPT predicts this broader payoff. Product innovation is more visible to external stakeholders than process change and therefore requires less embedding depth to generate market and reputational returns. Eco-designed products signal responsibility directly to customers, regulators, and communities—a mechanism that operates swiftly even in contexts where institutional enforcement is uneven. This helps explain why the economic and social returns of PDI appear robust across diverse settings, whereas the economic payoff of PCI remains maturity-dependent.

Direct GSCMP–performance effects (H5a–c)

GSCMP are also directly and positively associated with ENP (H5a), ECP (H5b), and SP (H5c), confirming partial rather than full mediation. Wiredu *et al.* (2024) and Gelmez *et al.* (2024) documented direct environmental effects in China and Turkey, respectively. Agyabeng-Mensah *et al.* (2025) and Fontoura and Coelho (2022) reported economic gains in Ghana and Portugal, while Zaidi and Lakhal (2025) and Morán *et al.* (2025) demonstrated social performance effects in Tunisia and Latin America. From a PBV perspective, these direct effects likely reflect coordination benefits, compliance visibility, and partner alignment that generate value independently of innovation, suggesting that GSCMP bundles operate through multiple channels simultaneously.

Mediation effects (H6a–c, H7a–c)

PCI mediates the relationship between GSCMP and ENP (H6a) and SP (H6c), but not ECP (H6b), mirroring the direct-effect pattern and reinforcing the maturity argument: economic value capture through process innovation remains constrained in the short run. PDI, by contrast, mediates all three outcomes (H7a–c), confirming it as the more immediate and complete transmission mechanism. Truong (2025) provides global patent evidence for both mediation channels, Čater *et al.* (2025) confirm them as distinct pathways in Europe, and Le and Govindan (2024), Appiah and Essuman (2024), and Morán *et al.* (2025) support the economic mediation of PDI across Vietnam, Ghana, and Latin America.

The blocked economic mediation through PCI (H6b) aligns with a growing consensus that this pathway is timing-dependent rather than structurally absent. Xie *et al.*'s (2022) U-shaped findings suggest that the indirect economic channel activates only after firms surpass a critical implementation threshold; prior to this point, early-stage cost pressures obscure mediation effects. Ai *et al.* (2024) further demonstrate that high financial leverage intensifies this early-stage penalty, making mediation particularly difficult to detect in cross-sectional designs such as the present study. Appiah *et al.* (2025) add that process innovation yields financial returns only in conjunction with co-creative customer relationships and a deliberate green strategy—conditions not yet pervasive among many emerging-economy manufacturers.

Through the PBV × NPT lens, NPT's intensive embedding work takes time to translate process routines into economic returns, while product-level innovations are immediately market-facing and monetisable. Consequently, H6b reflects a latent rather than broken pathway, contingent on implementation maturity, financial slack, and complementary resource orchestration—conditions that future studies should explicitly examine as moderating factors.

Implications

Theoretical implications

This study advances green operations theory by combining the practice-based view (PBV) and normalization process theory (NPT) to explain how GSCMP are linked to sustainability via dual innovation pathways. We extend PBV from merely possessing practices to their enacted bundling: treating GSCMP as a second-order formative capability (green purchasing, manufacturing, design, and distribution) and observing strong effects on PCI and PDI demonstrate that advantage can arise from broadly available routines when they are coherently integrated across the supply chain. Moreover, the significant direct GSCMP → ENP, ECP, and SP relationships indicate that practice bundles generate value both through innovation and beyond it (e.g., coordination, partner alignment, and compliance visibility), positioning partial mediation as a key boundary condition for PBV.

Second, the results specify how the bundle pays off by distinguishing between two mechanisms: PDI and PCI. Empirically, PDI carries larger effects on economic and social performance, whereas PCI is the more reliable route to environmental (and some social) gains, with an attenuated and non-significant link to economic performance. This sharpens PBV with a contingent value logic: the same practice bundle can generate market and relational value via PDI and efficiency or compliance value via PCI. The pattern invites theorization to consider payoff timing and complementarities (e.g., PCI's economic returns may require complementary investments or longer time horizons), rather than assuming uniform benefits across the triple bottom line.

Third, we elaborate PBV's microfoundations by integrating NPT. The strong GSCMP → PCI/PDI effects map onto NPT's embedding work: coherence (shared definitions of green practices), cognitive participation (cross-functional and partner buy-in), collective action (standardized green routines, audits, and joint problem-solving), and reflexive monitoring (performance feedback on emissions, defects, and resource use). This indicates that normalization work is the mechanism through which practice bundles become durable capabilities, enabling repeatable green innovation and subsequent performance gains. By demonstrating this role, we extend NPT beyond its traditional health and IT domains to explain practice embedding in supply chains, particularly in emerging-market manufacturing contexts where capability formation depends more on coordinated organizational work than on abundant formal resources.

Finally, by demonstrating a PBV–NPT framework in Indonesian manufacturing, the study offers an integrated lens for future research on sustainable operations: conceptualizing practice bundles as formative capabilities, tracing their effects through differentiated innovation routes, and modeling partial mediation alongside direct practice effects. This synthesis moves the field beyond simple "practice-to-performance" links toward a processual, mechanism-rich account of how green routines become normalized, generate specific types of innovation, and differentially translate into environmental, economic, and social outcomes.

Managerial implications

This study provides practical and actionable implications for Indonesian manufacturing firms. First, the findings underscore that green supply chain management works best when treated as a unified capability rather than as a collection of standalone initiatives. Firms can operationalize this by establishing a single cross-functional "green supply" program that aligns purchasing, operations, design, and distribution under one plan, one budget, and shared KPIs. Government bodies can support this coherence through procurement standards and supplier-readiness checklists that reward end-to-end alignment rather than isolated efforts.

Second, green product innovation provides the most credible lever for achieving expansive sustainability payoffs. Firms should incorporate eco-design considerations into the stage-gate process (e.g., recyclable or mono-materials, modular components, and lower embodied energy), align R&D with key suppliers and customers, and introduce life-cycle assessment early in product development so that environmental benefits translate into market value. These efforts can be strengthened through policy support such as matching grants and expedited certification for eco-labelled products (e.g., SNI eco-labels), enabling greener SKUs to compete more effectively in domestic and export tenders.

Third, green process innovation consistently improves environmental and social outcomes, even though cost benefits may materialize more slowly. One practical path is to formalize energy, water, and material audits; address yield losses using Lean and Total Productive Management tools; and install submeters and digital dashboards to translate improvements into cost-per-unit, emissions, and health, safety, and environment (HSE) indicators. These routines can be linked to supplier scorecards and logistics practices (e.g., returnable packaging, route consolidation, and modal shifts) to extend performance gains beyond the plant boundary. Regulators can accelerate adoption by offering utility rebates and concessional financing for metering, retrofits, and cleaner technologies.

Fourth, because green supply practices also influence performance directly, firms should embed them into day-to-day operations. This includes setting plant-level environmental targets, linking a portion of incentives to eco-design milestones and verified reductions, appointing line-level champions, and conducting regular performance reviews. Short, frequent training sessions, standardized work procedures, and after-action reviews help institutionalize greener routines across sites. Transparent recognition programs (such as the Company Performance Rating Assessment Program) can further signal these efforts to markets and local communities, building trust and contractual resilience.

Finally, overcoming adoption barriers requires ecosystem-level coordination. Industry associations and anchor firms can jointly implement supplier development initiatives (e.g., Kaizen programs focused on materials and packaging), share testing and certification infrastructure for SMEs, and structure green-credit facilities that lower the cost of compliance-related investments. Simple digital disclosures—such as QR-linked product information and verified environmental footprints—enable credible firms to signal improvements to buyers and communities, reducing perceived risk and accelerating the diffusion of greener products and processes across Indonesia's manufacturing sector.

Conclusions

This study addressed three research questions. Regarding RQ1, the findings confirm that integrated GSCMP strongly and positively stimulate both PCI ($\beta = 0.799$) and PDI ($\beta = 0.778$), supporting the view that coherently bundled green supply chain practices create the organisational conditions necessary for both process- and product-level eco-innovation. Regarding RQ2, PCI and PDI differ meaningfully in how they transmit GSCMP's effects: PDI mediates toward all three sustainability dimensions—environmental, economic, and social performance—making it the more immediate and complete transmission channel, whereas PCI mediates only toward environmental and social performance, with its economic channel remaining statistically non-significant. This suggests a maturity-dependent rather than a permanently absent pathway. Regarding RQ3, GSCMP also exert significant direct effects on all three performance dimensions, confirming partial rather than full mediation and indicating that end-to-end supply chain coordination generates sustainability value both through innovation and beyond it.

These results are important far beyond Indonesia. As discussed earlier, the pathways identified are consistent with results from Portugal, Spain, Slovenia, Tunisia, Ghana, and Latin America (Fontoura & Coelho, 2022; Martínez-Falcó *et al.*, 2024; Čater *et al.*, 2025; Zaidi & Lakhal, 2025; Agyabeng-Mensah *et al.*, 2025; Appiah & Essuman, 2024; Morán *et al.*, 2025). Indonesia's manufacturing base—a mix of small workshops and large export-oriented companies, characterised by patchy regulation and uneven supplier quality—concentrates challenges faced by manufacturers worldwide: how to remain competitive while going green. The headline takeaway is not country-specific: product eco-design delivers faster and broader performance payoffs across all three sustainability pillars, whereas process greening requires time, complementary capabilities, and consistency in partnering before financial benefits materialise. Managers and policymakers in Europe or North America confront the same trade-offs. In this sense, Indonesia functions less as a local case and more as a real-world testbed for greening supply chains globally.

This research shows that treating GSCMP as an embedded capability—through green purchasing, manufacturing, design, and distribution—strengthens both PDI and PCI in Indonesian manufacturing firms. PDI is positively associated with ENP, ECP, and SP, while PCI is linked to ENP and SP but not ECP. Beyond these mediated pathways, GSCMP also directly enhance triple-bottom-line outcomes, underscoring the value of end-to-end coordination and partner alignment. Overall, the findings support a PBV × NPT perspective: common practices become strategic when they are routinised and deeply institutionalised across interfirm activities.

This study has several limitations. First, all 34 substantive items are perceptual self-reports measured on a Likert scale. In addition, items referring to changes "during the last three years" (e.g., ENP and SP indicators) rely on respondents' long-term recall, which may introduce social desirability and memory bias. Second, constructs such as economic performance reflect outcomes that could be objectively measured—such as waste ratios, material costs, return on investment, or earnings per share—but the questionnaire captures managerial perceptions rather than verified operational metrics. Consequently, reported improvements cannot be conclusively linked to objective performance changes. Third, the cross-sectional, single-informant design captures one perspective at a single point in time, preventing strong causal claims about the directionality of the GSCMP–innovation–performance relationships.

Each of these limitations offers opportunities for future research. To circumvent reliance on self-reported measures, researchers could triangulate survey responses with hard operational records, such as audited utility bills, certified waste logs, or publicly disclosed sustainability reports. To overcome the limitations of a cross-sectional design, longitudinal or panel studies could track the evolution of GSCMP adoption processes over time and enable stronger causal inference. Finally, to minimise single-rater bias, future work could adopt multi-informant designs that incorporate perspectives from operations, procurement, and sustainability functions within the same firm, combined with mixed-method approaches such as on-site case studies, thereby enhancing both the reliability and the richness of empirical insights.

References

Aftab, J., Abid, N., Cucari, N., & Savastano, M. (2023). Green human resource management and environmental performance: The role of green innovation and environmental strategy in a developing country. *Business Strategy and the Environment, 32*(4), 1782–1798. https://doi.org/10.1002/bse.3219.

Agyabeng-Mensah, Y., Oloruntoba, R., Earnest, J., & Mohammadi, H. (2025). Sustainable supply chain management and performance outcomes: Supply chain practice view and mediated moderation perspectives. *Business Strategy and the Environment, 34*(7), 8237–8258. https://doi.org/10.1002/bse.70023.

Ai, M., Luo, F., & Bu, Y. (2024). Green innovation and corporate financial performance: Insights from operating risks. *Journal of Cleaner Production, 456*, 142353. https://doi.org/10.1016/j.jclepro.2024.142353.

Appiah, L. O., & Essuman, D. (2024). How do firms develop and financially benefit from green product innovation in a developing country? Roles of innovation orientation and green marketing innovation. *Business Strategy and the Environment, 33*(7), 7241–7252. https://doi.org/10.1002/bse.3864.

Appiah, L. O., Essuman, D., Forson, C. A., Boso, N., & Annan, J. (2025). Green process innovation and financial performance in small and medium-sized enterprises in a developing country: Role of resource orchestration. *Journal of Business Research, 189*, 115210. https://doi.org/10.1016/j.jbusres.2025.115210.

Asian Development Bank. (2023). *Transition from coals to renewable energy: Evidence from Indonesia*. https://www.adb.org/publications/transition-from-coals-to-renewable-energy-evidence-from-indonesia.

Badan Pusat Statistik. (2023). *Business characteristics statistics 2022/2023*. Central Statistics Agency of Indonesia. https://www.bps.go.id/en/publication/2023/12/22/140fcce371d95181d426827c/business-characteristics-statistics-2022-2023.html.

Baumgartner, H., & Weijters, B. (2021). Structural equation modeling. In *Handbook of market research* (pp. 1–38). Springer. https://doi.org/10.1007/978-3-319-57413-4_14.

Begum, S., Xia, E., Ali, F., Awan, U., & Ashfaq, M. (2022). Achieving green product and process innovation through green leadership and creative engagement in manufacturing. *Journal of Manufacturing Technology Management, 33*(4), 656–674. https://doi.org/10.1108/JMTM-01-2021-0003.

Bromiley, P., & Rau, D. (2014). Toward a practice-based view of strategy. *Strategic Management Journal, 35*(8), 1249–1256. https://doi.org/10.1002/smj.2238.

Čater, T., Uršič, D., Čater, B., & Žabkar, V. (2025). The nexus of technological innovation, green product/process innovation and environmental strategy: The path toward sustainability-based competitive advantage. *Technology Analysis & Strategic Management*, 1–15. https://doi.org/10.1080/09537325.2025.2486010.

Elkington, J., & Rowlands, I. H. (1999). Cannibals with forks: The triple bottom line of 21st century business. *Alternatives Journal*, *25*(4), 42.

Epoh, R. L., Langton, I., & Mafini, C. (2024). A model for green supply chain management in the South African manufacturing sector. *Cogent Business & Management, 11*(1), 2390213. https://doi.org/10.1080/23311975.2024.2390213.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149.

Falk, R. F., & Miller, N. B. (1992). *A primer for soft modeling*. University of Akron Press.

Feng, Y., Lai, K. H., & Zhu, Q. (2022). Green supply chain innovation: Emergence, adoption, and challenges. *International Journal of Production Economics, 248*, 108497. https://doi.org/10.1016/j.ijpe.2022.108497.

Fontoura, P., & Coelho, A. (2022). How to boost green innovation and performance through collaboration in the supply chain: Insights into a more sustainable economy. *Journal of Cleaner Production*, *359*, 132005. https://doi.org/10.1016/j.jclepro.2022.132005.

Gelmez, E., Özceylan, E., & Mrugalska, B. (2024). The impact of green supply chain management on green innovation, environmental performance, and competitive advantage. *Sustainability*, *16*(22), 9757. https://doi.org/10.3390/su16229757.

Hair, J., Hollingsworth, C. L., Randolph, A. B., & Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management & Data Systems, 117*(3), 442–458. https://doi.org/10.1108/IMDS-04-2016-0130.

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science, 43*, 115–135. https://doi.org/10.1007/s11747-014-0403-8.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118.

International Energy Agency. (2022). *An energy sector roadmap to net zero emissions in Indonesia*. https://www.iea.org/reports/an-energy-sector-roadmap-to-net-zero-emissions-in-indonesia.

Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of e-Collaboration, 11*(4), 1–10. https://doi.org/10.4018/ijec.2015100101.

Le, T. T., & Govindan, K. (2024). Boosting green innovation on corporate performance: Managerial environmental concern's moderating role. *Business Strategy and the Environment, 33*(7), 6254–6274. https://doi.org/10.1002/bse.3795.

Li, G., Li, L., Choi, T. M., & Sethi, S. P. (2020). Green supply chain management in Chinese firms: Innovative measures and the moderating role of quick response technology. *Journal of Operations Management, 66*(7–8), 958–988. https://doi.org/10.1002/joom.1061.

Martínez-Falcó, J., Sánchez-García, E., Marco-Lajara, B., & Lee, K. (2024). Green supply chain management and sustainable performance: Exploring the role of green ambidexterity innovation and top management environmental awareness. *Business Process Management Journal, 30*(6), 1824–1847. https://doi.org/10.1108/BPMJ-12-2023-0981.

May, C., & Finch, T. (2009). Implementing, embedding, and integrating practices: An outline of normalization process theory. *Sociology, 43*(3), 535–554. https://doi.org/10.1177/0038038509103208.

Mohsin, A. K. M., Schmidt, V., Aschauer, F., Plasch, M., & Gerschberger, M. (2025). Examining the evolution of sustainable supply chain management: A systematic review and bibliometric analysis. *Sustainable Development, 33*(6), 8213–8238. https://doi.org/10.1002/sd.70093.

Morán, P. D. T., Fan, M., & Sampene, A. K. (2025). Green supply chain management to spur economic, social, and environmental performance: Novel insight from Latin American countries. *Business Strategy and the Environment, 34*(4), 4518–4540. https://doi.org/10.1002/bse.4198.

Negi, R., Gupta, A. K., & Gaur, V. (2023). Effect of green marketing orientation dimensions on green innovation and organizational performance: A mediation–moderation analysis. *Business Strategy and the Environment, 32*(8), 5435–5458. https://doi.org/10.1002/bse.3429.

Nguyen, L. Q., & Nguyen, T. N. (2025). Exploring the relationship of green HRM practices with sustainable performance: The mediating effect of green innovation. *Journal of Hospitality and Tourism Insights, 8*(8), 2792–2814. https://doi.org/10.1108/JHTI-06-2024-0610.

Sarstedt, M., Hair, J. F., Cheah, J. H., Becker, J. M., & Ringle, C. M. (2019). How to specify, estimate, and validate higher-order constructs in PLS-SEM. *Australasian Marketing Journal, 27*(3), 197–211. https://doi.org/10.1016/j.ausmj.2019.05.003.

Singh, R. K., Mishra, R., & He, Q. (2025). Sustainable supply chain and environmental collaboration in supply chain management: Agenda for future research and implications. *Business Strategy and the Environment, 34*(5), 5487–5513. https://doi.org/10.1002/bse.4136.

Truong, Y. (2025). Green innovations and toxic emissions of manufacturing firms: Do green innovative firms pollute less? *Corporate Social Responsibility and Environmental Management*, *32*(5), 6831–6842. https://doi.org/10.1002/csr.70065.

Umar, M., Khan, S. A. R., Yusliza, M. Y., Ali, S., & Yu, Z. (2022). Industry 4.0 and green supply chain practices: An empirical study. *International Journal of Productivity and Performance Management, 71*(3), 814–832. https://doi.org/10.1108/IJPPM-12-2020-0633.

Wiredu, J., Yang, Q., Sampene, A. K., Gyamfi, B. A., & Asongu, S. A. (2024). The effect of green supply chain management practices on corporate environmental performance: Does supply chain competitive advantage matter? *Business Strategy and the Environment*, *33*(3), 2578–2599. https://doi.org/10.1002/bse.3606.

World Bank. (2023). *Enterprise surveys: Indonesia 2023 country profile*. The World Bank Group. https://www.enterprisesurveys.org/content/dam/enterprisesurveys/documents/country/Indonesia-2023.pdf.

Xie, X., Hoang, T. T., & Zhu, Q. (2022). Green process innovation and financial performance: The role of green social capital and customers' tacit green needs. *Journal of Innovation & Knowledge, 7*(1), 100165. https://doi.org/10.1016/j.jik.2022.100165.

Xiong, Z., Liu, J., Shi, D., & Hu, J. (2025). From chains to gains: How green supply chain management drives green innovation in Chinese manufacturing. *International Review of Financial Analysis*, 104579. https://doi.org/10.1016/j.irfa.2025.104579.

Xu, J., Yu, Y., Zhang, M., & Zhang, J. Z. (2023). Impacts of digital transformation on eco-innovation and sustainable performance: Evidence from Chinese manufacturing companies. *Journal of Cleaner Production, 393*, 136278. https://doi.org/10.1016/j.jclepro.2023.136278.

Younis, H., Bwaliez, O. M., Garibeh, M. H., & Sundarakani, B. (2025). Empirical study of robotic systems implementation to corporate performance in manufacturing sector. *International Journal of Productivity and Performance Management, 74*(5), 1479–1506. https://doi.org/10.1108/IJPPM-02-2024-0070.

Zaidi, A., & Lakhal, L. (2025). The impact of lean manufacturing practices on green supply chain management and corporate sustainable performance: Evidence from manufacturing firms operating in Tunisia. *International Journal of Productivity and Performance Management, 74*(10), 3423–3454. https://doi.org/10.1108/IJPPM-07-2024-0448.

Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the authors. Extracting and inspecting publicly accessible files (scholarly sources) as evidence, before the research began no institutional ethics approval was required.

Data availability statement

All data generated or analyzed are included in the published article. The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation. The raw anonymized data can be provided by emailing the primary author.

Author contributions

All listed authors have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the source analysis.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Annex

Table 1. Previous studies and gap identification

Author (s)	Context	Mediating Variable (s)	Variables Used	Main Findings	Research Gaps Identified
Nguyen & Nguyen, 2024	Hospitality Industry	Yes, green product innovation and green process innovation	Green HRM, Green product innovation, green process innovation, economic performance, environmental performance, and social performance	Green job descriptions and analysis, green performance management, green health and safety, green involvement and empowerment and green discipline management that enhance green innovation and sustainable performance.	Does not analyze GSCMP
Li *et al.*, 2020	Manufacturing firms	No mediating variable	Green SCM pressures (Market, cost, export), GSCMP (internal, external improvements, ecology), quick response, and Green SCM performance	Market and export pressures affect GSCMP, cost pressure does not. Internal improvement affects GSCMP, external improvement practice negatively affects positive economic performance. Ecology affects environmental, positive economic, and operational performance. QR technology suppresses the positive effect between internal improvement and negative economic performance	Does not explore green innovation

Table 1. Continued

Author (s)	Context	Mediating Variable (s)	Variables Used	Main Findings	Research Gaps Identified
Gelmez *et al.*, 2024	Manufacturing firms	No mediating variable	GSCM practices, green innovation (GI), environmental performance (EP), and competitive advantage (CA)	GSCMP affects GI and CA; GSCMP affects ENP; GI affects CA; and ENP has no effect on CA	Does not analyze economic and environmental performance
Umar *et al.*, 2022	Manufacturing Industry	Yes, GSCMP	Industry 4.0, GSCMP (green purchasing, green manufacturing, green design, green training), environmental and economic performance)	GSCMP mediates the effect of Industry 4.0 on both economic and environmental performance. GSCMP is positively affected by Industry 4.0.	Does not analyze Green innovation and social performance
This study	Manufacturing firms	Yes, Green innovation (process and product innovation)	GSCMP, green product innovation, green process innovation, sustainable performance (economic performance, environmental performance, and social performance)	GSCMP as an embedded capability—via green purchasing, manufacturing, design, and distribution—strengthens both PDI and PCI in Indonesian manufacturing firms. PDI translates into ENP, ECP, and SP while PCI improves ENP and SP but not ECP	It analyzes GSCMP, green innovation, sustainable performance with green innovation as mediating variable

Table 2. Sample demographics

Measure	Category	Frequency	Percentage
Gender	Male	386	66.90%
	Female	191	33.10%
Age	20-29	74	12.82%
	30-39	219	37.95%
	40-49	188	32.58%
	≥50	96	16.64%
Education	High school and equivalent	51	8.84%
	Bachelor's degree	201	34.84%
	Master's degree	279	48.35%
	Doctoral degree	46	7.97%
Current Tenure	Supervisor	208	36.05%
	Manager	261	45.23%
	General Manager	47	8.15%
	Director	39	6.76%
	President/Owner	22	3.81%
Years in current tenure	<= 1 year	67	11.61%
	2-4 year(s)	166	28.77%
	5-7 years	204	35.36%
	8-10 years	101	17.50%
	>11 years	39	6.76%
Firm size	30-50 employees	93	16.12%
	51-100 employees	145	25.13%
	100-1,000 employees	177	30.68%
	1,001-5,000 employees	109	18.89%
	=> 5,001 employees	53	9.19%

Table 3. Operationalisation and measurement items

Variable	Operationalization	Measurement Items	Source
Green Purchasing (GP)	Green purchasing focuses on environmentally friendly development and processing of products that give no harm to the environment as well as it also includes cooperation with the supplier	1. The company ensures suppliers meet their environmental objectives 2. The company requires suppliers to have certified EMS like ISO 14001 3. The company ensures purchased materials contain green Attributes 4. The company evaluates suppliers on specific environmental criteria	Umar *et al.*, 2022
Green Manufacturing (GM)	Green production includes reduction of harmful waste from production process also it focuses on planning, controlling and reduction of means including water, energy and material	1. The company carries out green practices in manufacturing processes reducing fossil fuel energy consumption 2. The company uses green materials in manufacturing 3. The company decreases toxic and hazardous chemicals in manufacturing processes	Umar *et al.*, 2022
Green Design (GDes)	Green design helps in the reduction of waste through upgrading, recycling and remanufacturing as well as it also facilitates green purchasing, reverse logistics and green manufacturing	1. Design of products for reduced consumption of material/energy 2. Design of products for reuse, recycle, recovery of material, or components parts 3. Design of products to avoid or reduce use of hazardous products and their manufacturing process	Umar *et al.*, 2022
Green Distribution (GDis)	It entails all activities to reduce/eliminate environmental damages and wastes during shipment	1. The company has selected cleaner transportation methods 2. The company has implemented effective shipment consolidation and full vehicle loading 3. The company has applied routing systems to minimize travel distances	Epoh *et al.*, 2024
Green Product Innovation (PDI)	The performance in product innovation that is related to environmental innovation, including the innovation in product that are involved in energy-saving, pollution-prevention, waste recycling, no toxicity, or green product designs	1. The company uses less or non-polluting/toxic materials that are environmentally friendly 2. The company uses materials that are easy to recycle, reuse, and decompose 3. The company recovers company's end-of-life products and recycling 4. The company uses eco-labeling	Negi *et al.*, 2023

Table 3. Continued

Variable	Operationalization	Measurement Items	Source
Green Process Innovation (PCI)	The performance in process innovation that is related to energy-saving, pollution-prevention, waste recycling, or no toxic	1. The manufacturing process of the company effectively reduces the emission of hazardous substances or waste; 2. The manufacturing process of the company recycles waste and emission that allow them to be treated and re-used; 3. The manufacturing process of the company reduces the consumption of water, electricity, coal, or oil; 4. The manufacturing process of the company reduces the use of raw material	Begum *et al*., 2022
Environmental Performance (ENP	It pertains to the capability to minimize the use of harmful waste in the SC and also it pertains to the knack of growing plants to lessened emissions	1. The efficiency of the consumption of raw materials has improved during the last 3 years 2. The resource consumption (thermal energy, electricity, water) has decreased (e.g., per unit of income, per unit of production) during the last 3 years. 3. The percentage of recycled materials has increased during the last 3 years. 4. The waste ratio (e.g., kg per unit of product, kg per employee per year) has decreased during the last 3 years.	Umar *et al*., 2022
Economic Performance (ECP)	It pertains to the ability to reduce costs from the production process, including material and components purchasing, energy and water consumption and waste discharge	1. The company has decreased in cost of materials purchased 2. The company has decreased in cost of energy consumption 3. The company has decreased in fee for waste discharge 4. The company has improved its return on investment 5. The company has improved its earnings per share	Xu *et al*., 2023; Umar *et al*., 2022
Social Performance (SP)	Business organization's configuration of principles of social responsibility, processes of social responsiveness, and policies, programs and observable outcomes as they relate to the firm's societal relationships.	1. The corporate image has increased during the past 3 years 2. The social commitment has increased during the past 3 years 3. The environment preservation has increased during the past 3 years 4. The employees’ satisfaction has increased during the past 3 years.	Younis *et al*., 2025

Table 4. Convergent validity and reliability

Constructs	Items	Factor Loadings	Cronbach's Alpha (CA)	Composite Reliability (CR)	Average Variance Extracted (AVE)
Green Purchasing (GP)	GP1	0.728	0.822	0.831	0.655
	GP2	0.876			
	GP3	0.848			
	GP4	0.776			
Green Manufacturing (GM)	GM1	0.800	0.718	0.738	0.643
	GM2	0.889			
	GM3	0.707			
Green Design (GDes)	GDes1	0.823	0.841	0.854	0.759
	GDes2	0.919			
	GDes3	0.868			
Green Distribution (GDis)	GDis1	0.852	0.780	0.798	0.695
	GDis2	0.889			
	GDis3	0.755			
Green Process Innovation (PCI)	PCI1	0.756	0.799	0.809	0.624
	PCI2	0.848			
	PCI3	0.777			
	PCI4	0.776			
Green Product Innovation (PDI)	PDI1	0.762	0.778	0.790	0.599
	PDI2	0.821			
	PDI3	0.731			
	PDI4	0.781			
Environmental Performance (ENP)	ENP1	0.756	0.781	0.788	0.603
	ENP2	0.813			
	ENP3	0.771			
	ENP4	0.764			
Economical Performance (ECP)	ECP1	0.774	0.817	0.822	0.576
	ECP2	0.727			
	ECP3	0.741			
	ECP4	0.813			
	ECP5	0.739			
Social Performance (SP)	SP1	0.771	0.747	0.750	0.567
	SP2	0.747			
	SP3	0.731			
	SP4	0.764			

Note: FL: Factor Loading ≥ 0.7; CA: Cronbach's Alpha ≥ 0.7; CR: Composite Reliability ≥ 0.7; AVE: Average Variance Extracted ≥0.5.

Table 5. Fornell-Larcker Criterion

Construct	GP	GMan	GDes	GDis	PCI	PDI	ENP	ECP	SP
GP	**0.809**	0.534	0.611	0.655	0.757	0.732	0.625	0.566	0.601
GMan	0.534	**0.802**	0.588	0.557	0.528	0.523	0.489	0.473	0.494
GDes	0.611	0.588	**0.871**	0.681	0.590	0.593	0.523	0.478	0.541
GDis	0.655	0.557	0.681	**0.834**	0.686	0.666	0.576	0.510	0.578
PCI	0.757	0.528	0.590	0.686	**0.790**	0.790	0.669	0.536	0.619
PDI	0.732	0.523	0.593	0.666	0.790	**0.774**	0.691	0.634	0.631
ENP	0.625	0.489	0.523	0.576	0.669	0.691	**0.776**	0.725	0.782
ECP	0.566	0.473	0.478	0.510	0.536	0.634	0.725	**0.759**	0.755
SP	0.601	0.494	0.541	0.578	0.619	0.631	0.782	0.755	**0.753**

Notes: The diagonal and bold values are the square roots of AVE.

Table 6. The HTMT

Construct	GP	GMan	GDes	GDis	PCI	PDI	ENP	ECP	SP
GP	—	0.689	0.724	0.811	0.825	0.810	0.768	0.678	0.759
GMan	0.689	—	0.755	0.737	0.687	0.692	0.644	0.609	0.664
GDes	0.724	0.755	—	0.831	0.708	0.727	0.637	0.564	0.674
GDis	0.811	0.737	0.831	—	0.837	0.840	0.728	0.628	0.747
PCI	0.825	0.687	0.708	0.837	—	0.794	0.836	0.648	0.788
PDI	0.810	0.692	0.727	0.840	0.794	—	0.833	0.776	0.813
ENP	0.768	0.644	0.637	0.728	0.836	0.833	—	0.834	0.812
ECP	0.678	0.609	0.564	0.628	0.648	0.776	0.834	—	0.758
SP	0.759	0.664	0.674	0.747	0.788	0.813	0.812	0.758	—

Notes: The values in the parenthesis represents HTMT value with < 0.85 is strong,
< 0.90 moderate and < 0.95 weak.

Table 7. Cross-Loadings Matrix

Indicator	GP	GMan	GDes	GDis	PCI	PDI	ENP	ECP	SP
GP1	**0.728**	0.369	0.457	0.522	0.551	0.563	0.434	0.401	0.491
GP2	**0.876**	0.499	0.586	0.625	0.678	0.679	0.604	0.589	0.579
GP3	**0.848**	0.454	0.487	0.518	0.607	0.582	0.506	0.451	0.460
GP4	**0.776**	0.396	0.433	0.442	0.607	0.534	0.463	0.368	0.403
GMan1	0.419	**0.800**	0.400	0.387	0.371	0.373	0.381	0.409	0.367
GMan2	0.493	**0.889**	0.503	0.497	0.493	0.474	0.470	0.471	0.450
GMan3	0.362	**0.707**	0.504	0.446	0.394	0.402	0.314	0.244	0.362
GDes1	0.437	0.485	**0.823**	0.493	0.424	0.452	0.376	0.319	0.411
GDes2	0.565	0.523	**0.919**	0.611	0.522	0.543	0.491	0.454	0.484
GDes3	0.577	0.525	**0.868**	0.657	0.580	0.545	0.487	0.459	0.509
GDis1	0.529	0.462	0.627	**0.852**	0.592	0.549	0.436	0.388	0.454
GDis2	0.617	0.524	0.585	**0.889**	0.631	0.628	0.553	0.516	0.540
GDis3	0.483	0.399	0.486	**0.755**	0.481	0.478	0.446	0.360	0.446
PCI1	0.670	0.401	0.484	0.551	**0.756**	0.601	0.507	0.357	0.470
PCI2	0.682	0.490	0.529	0.624	**0.848**	0.670	0.596	0.530	0.561
PCI3	0.505	0.369	0.406	0.494	**0.777**	0.583	0.496	0.412	0.465
PCI4	0.514	0.397	0.433	0.483	**0.776**	0.641	0.505	0.377	0.450
PDI1	0.562	0.385	0.494	0.519	0.656	**0.762**	0.496	0.450	0.484
PDI2	0.616	0.479	0.492	0.616	0.684	**0.821**	0.633	0.640	0.570
PDI3	0.508	0.397	0.415	0.489	0.528	**0.731**	0.473	0.397	0.427
PDI4	0.572	0.346	0.430	0.464	0.563	**0.781**	0.516	0.440	0.457
ENP1	0.502	0.332	0.381	0.423	0.483	0.507	**0.756**	0.498	0.610
ENP2	0.584	0.438	0.453	0.549	0.611	0.609	**0.813**	0.683	0.652
ENP3	0.402	0.344	0.340	0.402	0.509	0.500	**0.771**	0.510	0.553
ENP4	0.435	0.396	0.445	0.395	0.458	0.517	**0.764**	0.539	0.609
ECP1	0.493	0.395	0.435	0.451	0.500	0.551	0.624	**0.774**	0.572
ECP2	0.385	0.305	0.287	0.306	0.321	0.434	0.511	**0.727**	0.523
ECP3	0.388	0.342	0.356	0.347	0.345	0.455	0.494	**0.741**	0.568
ECP4	0.481	0.385	0.358	0.408	0.451	0.492	0.590	**0.813**	0.617
ECP5	0.383	0.358	0.362	0.407	0.390	0.461	0.516	**0.739**	0.584
SP1	0.442	0.309	0.433	0.416	0.420	0.467	0.584	0.530	**0.771**
SP2	0.490	0.425	0.428	0.512	0.546	0.541	0.677	0.630	**0.747**
SP3	0.405	0.315	0.329	0.406	0.432	0.419	0.530	0.485	**0.731**
SP4	0.463	0.424	0.432	0.389	0.449	0.458	0.544	0.611	**0.764**

Table 8. The results of direct effect hypothesis testing

Hypothesis	Path coefficients	T-statistics	P-values	Remarks
H.1 GSCMP -> PCI	0.799***	45.483	0.000	Supported
H.2 GSCMP -> PDI	0.778***	35.442	0.000	Supported
H.3a PCI -> ENP	0.201**	2.711	0.007	Supported
H.3b PCI -> ECP	-0.074n.s.	0.940	0.347	Not Supported
H.3c PCI -> SP	0.134*	2.001	0.045	Supported
H.4a PDI ->ENP	0.332***	4.872	0.000	Supported
H.4b PDI -> ECP	0.430***	5.816	0.000	Supported
H.4c PDI -> SP	0.231***	3.631	0.000	Supported
H.5a GSCMP -> ENP	0.257***	3.711	0.000	Supported
H.5b GSCMP -> ECP	0.337***	4.688	0.000	Supported
H.5c GSCMP -> SP	0.377***	5.981	0.000	Supported

Notes: Significance level with ***P < 0.001; **P < 0.01; *P < 0.05

Table 9. Summary of indirect effect hypothesis testing

Hypothesis	β	T-Value	Bootstrapping CI 97.5% (N=5000)		
			Min	Max	Decision
H6a GSCMP-> PCI -> ENP	0.161**	2.680	0.038	0.274	Supported
H6b GSCMP-> PCI -> ECP	-0.059n.s.	0.940	-0.186	0.058	Not Supported
H6c GSCMP-> PCI -> SP	0.107*	1.978	0.000	0.212	Supported
H7a GSCMP->PDI-> ENP	0.258***	4.697	0.155	0.372	Supported
H7b GSCMP->PDI-> ECP	0.335***	6.018	0.220	0.438	Supported
H7c GSCMP->PDI-> SP	0.180***	3.538	0.087	0.286	Supported

Figure 1. Research framework

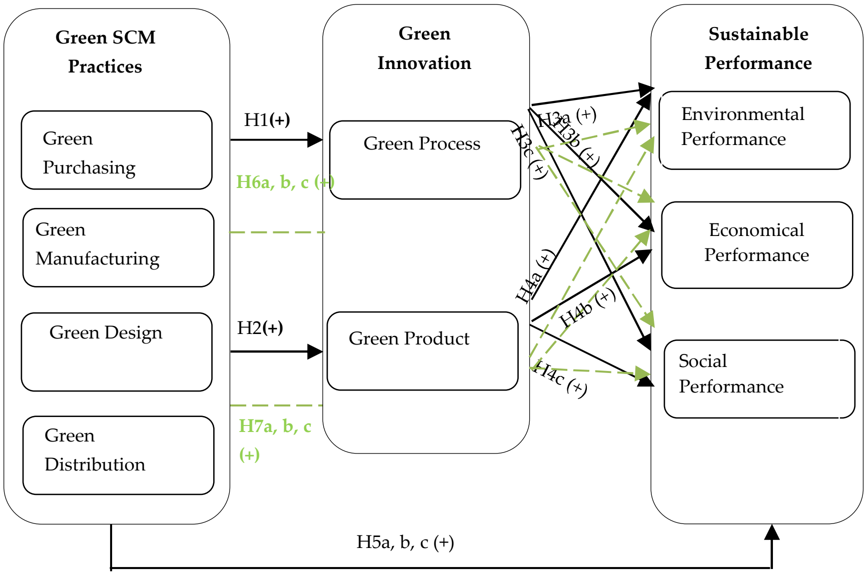
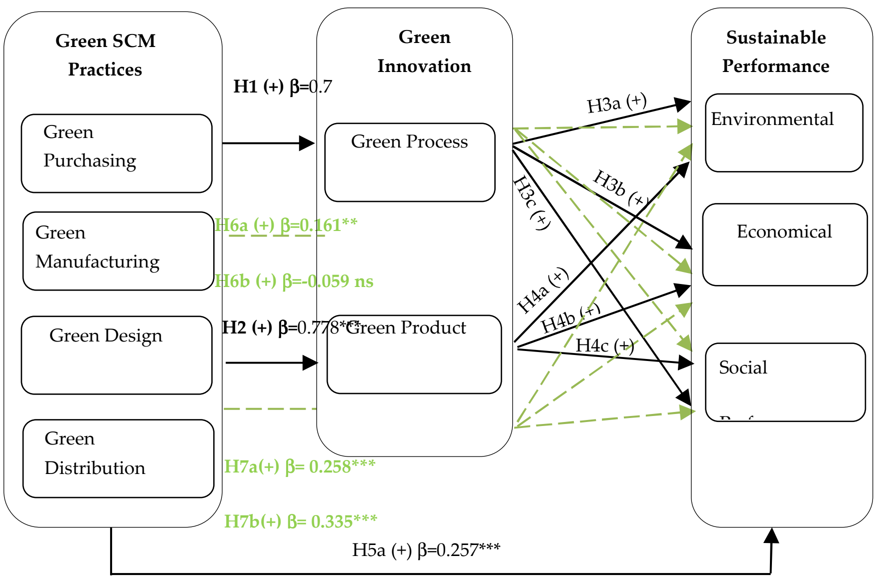


Figure 2. Hypothesis Testing Summary



H5b (+) β=0.337***

Notes:
H3a (+) β=0.201**; H3b (+) β= -0.074n.s.; H3c (+) β=0.134*; H4a (+) β=0.332***; H4b (+) β=0.430***; H4c (+) β=0.231***

Appendix

Research Instrument (Survey Questionnaire) Green Supply Chain Management, Green Innovation, and Sustainable Performance in Indonesian Manufacturing Firms

Informed Consent

Dear Respondent,

You are invited to participate in an academic research study on green supply chain management practices, green innovation, and sustainable performance in Indonesian manufacturing firms. This survey is conducted for scientific research purposes only.

Your participation is entirely voluntary and anonymous. No personally identifiable information (such as your name or email address) will be collected through this questionnaire. You may withdraw from the survey at any time without consequence. All responses will be kept confidential and reported only in aggregate form. This study is conducted in accordance with the principles of the Declaration of Helsinki for research involving human subjects.

The questionnaire takes approximately 10-15 minutes to complete. By ticking the box below, you confirm that you have read and understood the above information and agree to participate.

☐ **I agree to participate in this study**

SECTION A: Demographic and Firmographic Profile

Please tick (✓) the appropriate box for each question.

1. Gender

- ☐ Male
- ☐ Female

2. Age

- ☐ 20-29 years
- ☐ 30-39 years
- ☐ 40-49 years
- ☐ 50 years or above

3. Highest level of education completed

- ☐ High school and equivalent
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Doctoral degree

4. Current managerial position

- ☐ Supervisor
- ☐ Manager
- ☐ General Manager
- ☐ Director
- ☐ President / Owner

5. Years in current position

- ☐ 1 year or less
- ☐ 2-4 years
- ☐ 5-7 years

- ☐ 8-10 years
- ☐ 11 years or more

6. Number of employees in your firm

- ☐ 30-50 employees
- ☐ 51-100 employees
- ☐ 100-1,000 employees
- ☐ 1,001-5,000 employees
- ☐ 5,001 employees or more

SECTION B: Measurement Items

Please indicate your level of agreement with each statement below using the following scale:

1 = Strongly Disagree (SD) 2 = Disagree (D) 3 = Somewhat Disagree (SwD) 4 = Neutral (N) 5 = Somewhat Agree (SwA) 6 = Agree (A) 7 = Strongly Agree (SA)

Green Purchasing

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The company ensures suppliers meet their environmental objectives	GP1	☐	☐	☐	☐	☐	☐	☐
The company requires suppliers to have certified EMS like ISO 14001	GP2	☐	☐	☐	☐	☐	☐	☐
The company ensures purchased materials contain green attributes	GP3	☐	☐	☐	☐	☐	☐	☐
The company evaluates suppliers on specific environmental criteria	GP4	☐	☐	☐	☐	☐	☐	☐

Green Manufacturing

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The company carries out green practices in manufacturing processes reducing fossil fuel energy consumption	GM1	☐	☐	☐	☐	☐	☐	☐
The company uses green materials in manufacturing	GM2	☐	☐	☐	☐	☐	☐	☐
The company decreases toxic and hazardous chemicals in manufacturing processes	GM3	☐	☐	☐	☐	☐	☐	☐

Green Design

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
Design of products for reduced consumption of material/energy	GDes1	☐	☐	☐	☐	☐	☐	☐
Design of products for reuse, recycle, recovery of material, or component parts	GDes2	☐	☐	☐	☐	☐	☐	☐
Design of products to avoid or reduce use of hazardous products and their manufacturing process	GDes3	☐	☐	☐	☐	☐	☐	☐

Quality Check

For quality assurance purposes, please select 'Agree' (6) for this item	AC1	☐	☐	☐	☐	☐	☐	☐

Green Distribution

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The company has selected cleaner transportation methods	GDis1	☐	☐	☐	☐	☐	☐	☐
The company has implemented effective shipment consolidation and full vehicle loading	GDis2	☐	☐	☐	☐	☐	☐	☐
The company has applied routing systems to minimize travel distances	GDis3	☐	☐	☐	☐	☐	☐	☐

Green Process Innovation

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The manufacturing process of the company effectively reduces the emission of hazardous substances or waste	PCI1	☐	☐	☐	☐	☐	☐	☐
The manufacturing process of the company recycles waste and emission that allow them to be treated and re-used	PCI2	☐	☐	☐	☐	☐	☐	☐
The manufacturing process of the company reduces the consumption of water, electricity, coal, or oil	PCI3	☐	☐	☐	☐	☐	☐	☐
The manufacturing process of the company reduces the use of raw material	PCI4	☐	☐	☐	☐	☐	☐	☐

Green Product Innovation

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The company uses less or non-polluting/toxic materials that are environmentally friendly	PDI1	☐	☐	☐	☐	☐	☐	☐
The company uses materials that are easy to recycle, reuse, and decompose	PDI2	☐	☐	☐	☐	☐	☐	☐
The company recovers end-of-life products and recycling	PDI3	☐	☐	☐	☐	☐	☐	☐
The company uses eco-labeling	PDI4	☐	☐	☐	☐	☐	☐	☐

Quality Check

This is a data quality item. Please select 'Strongly Agree' (7) for this statement	AC2	☐	☐	☐	☐	☐	☐	☐

Environmental Performance

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The efficiency of the consumption of raw materials has improved during the last 3 years	ENP1	☐	☐	☐	☐	☐	☐	☐
The resource consumption (thermal energy, electricity, water) has decreased (e.g. per unit of income, per unit of production) during the last 3 years	ENP2	☐	☐	☐	☐	☐	☐	☐
The percentage of recycled materials has increased during the last 3 years	ENP3	☐	☐	☐	☐	☐	☐	☐
The waste ratio (e.g. kg per unit of product, kg per	ENP4	☐	☐	☐	☐	☐	☐	☐

employee per year) has decreased during the last 3 years								

Economic Performance

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The company has decreased in cost of materials purchased	ECP1	☐	☐	☐	☐	☐	☐	☐
The company has decreased in cost of energy consumption	ECP2	☐	☐	☐	☐	☐	☐	☐
The company has decreased in fee for waste discharge	ECP3	☐	☐	☐	☐	☐	☐	☐
The company has improved its return on investment	ECP4	☐	☐	☐	☐	☐	☐	☐
The company has improved its earnings per share	ECP5	☐	☐	☐	☐	☐	☐	☐

Social Performance

Statement	Code	1 SD	2 D	3 SwD	4 N	5 SwA	6 A	7 SA
The corporate image has increased during the past 3 years	SP1	☐	☐	☐	☐	☐	☐	☐
The social commitment has increased during the past 3 years	SP2	☐	☐	☐	☐	☐	☐	☐
The environment preservation has increased during the past 3 years	SP3	☐	☐	☐	☐	☐	☐	☐
The employees' satisfaction has increased during the past 3 years	SP4	☐	☐	☐	☐	☐	☐	☐

Thank you for your time and participation.

Note: *All substantive items in Section B are measured on a 7-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree). Items AC1 and AC2 are attention-check items used for data-quality screening and are not included.*

Note: The questionnaire was administered in *Bahasa Indonesia* (the Indonesian language). The English version presented here is the original instrument from which the Indonesian version was derived through a back-translation procedure.