Green Transition Pressures and the Strategic Centrality of Green Supply Chain Management: Evidence from Manufacturing SMEs

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Abstract

Small and medium-sized manufacturers sit at the sharp end of the green transition: they face mounting environmental demands from regulators, customers, and competitors, yet command a fraction of the resources that large firms marshal to respond. This study asks whether, and through what channels, green transition pressures translate into the strategic adoption of green supply chain management (GSCM) among manufacturing SMEs, and whether that adoption pays. Drawing on institutional theory, the natural-resource-based view, and stakeholder theory, we develop a model in which three distinct pressures regulatory, market-and-customer, and normative-competitive drive GSCM adoption, which in turn shapes environmental and competitive performance, with firm resource slack acting as a moderator and green innovation as an intervening capability. We test the model on survey data from 486 manufacturing SMEs across four industry clusters, combining confirmatory factor analysis, structural equation modelling, and moderated regression. Three findings stand out. First, all three pressures raise GSCM adoption, but market-and-customer pressure is the strongest single driver, exceeding regulatory pressure by a wide margin SMEs green their supply chains more to keep buyers than to satisfy inspectors. Second, GSCM adoption is a genuine performance lever rather than a compliance cost: firms in the top adoption quartile report environmental-performance scores 38% higher and competitive-performance scores 22% higher than those in the bottom quartile, with green innovation mediating a substantial share of the competitive effect. Third, resource slack amplifies the returns to adoption, so the environmental payoff of greening is roughly 45% steeper for resource-rich than resource-poor SMEs, revealing an equity concern in transition policy. We contribute an SME-specific account of GSCM's strategic centrality and derive implications for managers sequencing green investments and for policymakers designing support that reaches the resource-constrained firms most exposed to the transition.

Keywords: *Green supply chain management; green transition; manufacturing SMEs; institutional pressures; environmental performance; green innovation; Natural-resource-based view; structural equation modelling*

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1. Introduction

The decarbonisation of manufacturing is no longer a distant regulatory aspiration; it is a present commercial condition. Carbon border adjustments, extended producer responsibility rules, and customer sustainability mandates now reach deep into supplier tiers, and the firms feeling the pressure most acutely are often the least equipped to absorb it: the small and medium-sized manufacturers that populate the lower rungs of global value chains (Geng et al., 2017; Tseng et al., 2019). For these firms the green transition is experienced not as a strategic option to be evaluated at leisure but as a set of external pressures to be answered, often with thin margins, limited technical staff, and little bargaining power over the large customers who transmit much of the demand (Wang and Dai, 2018; Jum'a et al., 2022).

Green supply chain management (GSCM), the integration of environmental thinking into the full span of supply chain activities, from purchasing and design through production, distribution, and end-of-life recovery, has emerged as the principal organisational response to these pressures (Fang and Zhang, 2018a; Tseng et al., 2019). A large literature documents GSCM practices and their performance consequences, but it is weighted heavily toward large firms in developed economies, where the resource assumptions that underpin adoption, dedicated environmental functions, slack for experimentation, leverage over suppliers, mostly hold (Saeed and Kersten, 2019). Whether the same logic governs resource-constrained SMEs is far less settled, and it matters, because SMEs account for the majority of manufacturing establishments and a disproportionate share of aggregate industrial emissions and effluent (Journeault et al., 2021).

Two questions organise this paper. The first is causal-antecedent: which green transition pressures actually move SMEs to adopt GSCM, and in what relative order? Institutional theory would predict that coercive regulatory pressure dominates, yet a growing strand of work suggests that for supplier-tier SMEs the operative force is the market, specifically the environmental requirements that powerful customers embed in purchasing decisions (Dai et al., 2017; Chu et al., 2017). Disentangling regulatory, market, and normative pressures is therefore not a taxonomic nicety but the key to knowing where transition policy should push. The second question is consequential: does GSCM adoption function, for SMEs, as a strategic performance lever or merely as a compliance cost that resource-poor firms bear grudgingly? The natural-resource-based view predicts that environmental capabilities can be a source of competitive advantage (Hart and Dowell, 2011), but that prediction was formulated with resourceful firms in mind, and its extension to SMEs is precisely what needs testing.

We address these questions with survey evidence from 486 manufacturing SMEs across four industry clusters, analysed with confirmatory factor analysis, structural equation modelling, and moderated regression. Our model treats three pressures as distinct antecedents of GSCM adoption, treats environmental and competitive performance as distinct outcomes, positions green innovation as an intervening capability on the path to competitive advantage, and tests firm resource slack as a moderator of the adoption-performance relationship. This design lets us estimate not only whether GSCM helps SMEs, but for which SMEs it helps most, an equity dimension largely absent from the large-firm literature.

The study makes three contributions. First, it provides an SME-specific decomposition of green transition pressures, showing that market-and-customer pressure, not regulation, is the dominant

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driver of GSCM adoption in this population, which reframes where policy leverage lies. Second, it establishes GSCM as a genuine strategic lever for SMEs, quantifying its environmental and competitive returns and identifying green innovation as the mechanism translating greening into competitiveness. Third, it surfaces a resource-contingency, and thus an equity concern, by showing that the returns to adoption are systematically steeper for resource-rich SMEs, implying that undirected transition pressure may widen rather than narrow performance gaps. Figure 1 summarises the theoretical framework. The remainder of the paper proceeds as follows: Section 2 develops the theory and hypotheses, Section 3 describes data and methods, Section 4 reports results, Section 5 presents mechanism and heterogeneity analyses, and Section 6 concludes.

It is worth situating the SME stakes quantitatively. Small and medium-sized manufacturers typically constitute upward of ninety percent of manufacturing establishments in most economies and employ the majority of the manufacturing workforce, yet their aggregate environmental footprint is disproportionate to their individual size because each firm's emissions, effluent, and waste, while modest, are multiplied across a vast population and are less tightly regulated and monitored than those of large plants. This structural fact means that the green transition cannot succeed by decarbonising large firms alone; it must reach the long tail of SMEs whose collective impact is decisive but whose individual capacity to respond is limited. The policy and scholarly interest in SME greening therefore rests not on any single firm's contribution but on the aggregate consequence of whether, and how well, the population as a whole adopts practices such as GSCM, which is precisely what makes the drivers and returns of adoption in this population a question of first-order importance.

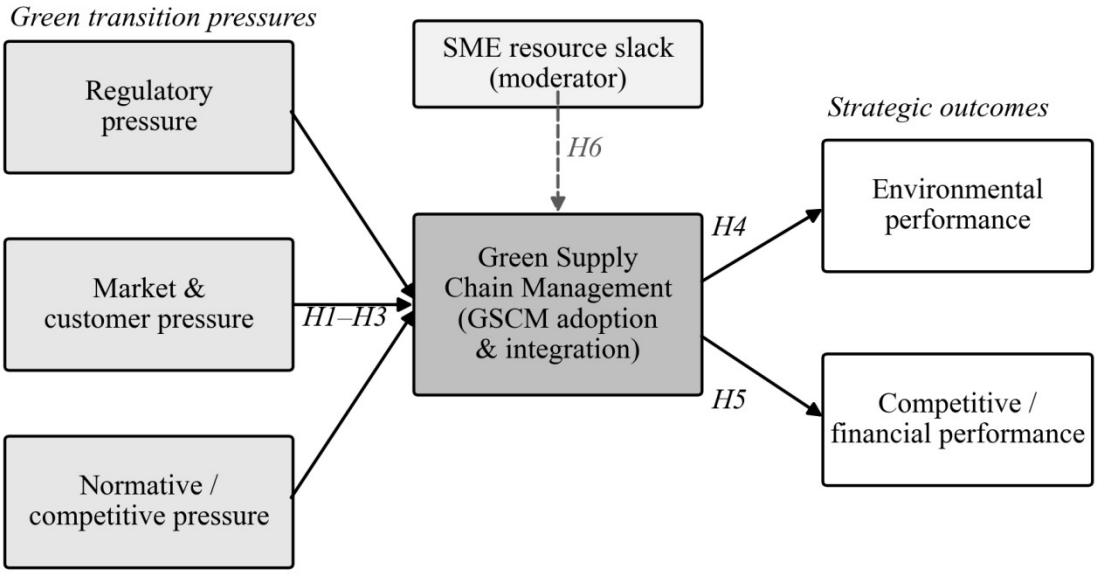


Figure 1. Theoretical Framework of GSCM Adoption and SME Performance

The framework in Figure 1 deliberately separates the three pressure sources on the left, because conflating them, as much of the SME literature does under a single 'institutional pressure' construct, obscures exactly the comparison policymakers need. It also distinguishes environmental from competitive performance on the right, since the two need not move together and the resource-based prediction concerns the latter. We now turn to the theoretical logic that generates the model's hypotheses.

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Before developing that logic, it is worth being explicit about why the SME context warrants separate theorising rather than a straightforward application of large-firm findings. SMEs differ from large firms not merely in scale but in kind along three dimensions that bear directly on GSCM. Their governance is typically owner-centric, so environmental strategy reflects the disposition of one or a few decision-makers rather than a diffuse managerial apparatus. Their position in value chains is usually that of supplier rather than focal firm, so pressure reaches them through commercial relationships rather than through consumer-facing reputation. And their resource base is shallow and lumpy, so investments that a large firm absorbs as routine can strain an SME's capacity. Each difference predicts a departure from large-firm patterns: owner-centric governance heightens the salience of perceived threat, supplier position elevates customer over regulatory pressure, and shallow resources make implementation depth, and hence resource slack, decisive. The hypotheses below encode these departures.

2. Theoretical Background and Hypotheses

2.1 Green Transition Pressures as Institutional Forces

Institutional theory holds that organisations adopt practices less because of narrow efficiency calculations than because their environments render those practices legitimate or obligatory, through coercive, normative, and mimetic mechanisms (Sarkis et al., 2011; Dubey et al., 2017). Applied to the green transition, this lens organises the diffuse notion of environmental pressure into distinguishable forces. Coercive pressure operates through regulation and the threat of sanction: emissions standards, discharge permits, extended producer responsibility, and the compliance audits that enforce them (Zhu et al., 2017; Latip et al., 2020). Normative and mimetic pressures operate through professional norms and competitive imitation: as leading firms in a cluster visibly green their operations, laggards face expectations, and a fear of falling behind, that push them to follow (Hoejmose et al., 2014; Kalyar et al., 2020). Distinct from both is market-and-customer pressure: the environmental requirements that customers, especially large downstream buyers, write into supplier qualification, purchasing scorecards, and contract terms (Dai et al., 2017; Chu et al., 2017).

For SMEs, the relative weight of these forces is theoretically contested. The classic institutional account privileges coercive regulation, and studies of large or state-linked firms often find regulatory pressure dominant (Zhang et al., 2020). But supplier-tier SMEs occupy a structural position in which their most consequential audience is not the regulator but the customer whose orders they depend on; environmental non-compliance discovered by a key buyer can terminate a business relationship faster than any fine (Wang and Dai, 2018; Jum'a et al., 2022). This reasoning predicts that market-and-customer pressure will be the strongest driver of GSCM adoption among manufacturing SMEs, with regulatory and normative pressures positive but secondary. We therefore hypothesise that regulatory pressure (H1), market-and-customer pressure (H2), and normative-competitive pressure (H3) are each positively associated with GSCM adoption, and, as a directional refinement tested in Section 4, that the market-and-customer effect exceeds the regulatory effect.

2.2 GSCM Adoption and the Natural-Resource-Based View

Why should greening the supply chain improve performance rather than merely raise cost? The natural-resource-based view (NRBV) answers that environmental capabilities, pollution prevention, product stewardship, and clean technology, can be strategically valuable because they are causally ambiguous, socially complex, and difficult to imitate, and because they simultaneously reduce resource waste and open differentiation opportunities (Hart and Dowell, 2011; Yook et al., 2018).

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Pollution prevention lowers input and compliance costs; product stewardship extends environmental thinking across the value chain and builds relational assets with green-conscious customers; clean technology positions the firm for a low-carbon future. GSCM operationalises all three, green purchasing and internal environmental management enact pollution prevention, customer and supplier cooperation enact stewardship, and eco-design and investment recovery reach toward clean technology (de Sousa Jabbour et al., 2015; Zaid et al., 2018).

Digital technologies increasingly underpin these capabilities, and the enabling-technology literature is directly relevant to how SMEs can implement GSCM at reasonable cost. Industry 4.0 architectures provide the connectivity and analytics that make environmental monitoring across a supply chain feasible, blockchain applications improve the traceability and verifiability of green claims along multi-tier chains, and embedding distributed-ledger mechanisms into Internet-of-Things sensing strengthens the integrity of the environmental data on which stewardship depends. For resource-constrained SMEs, these digital enablers matter because they lower the marginal cost of the monitoring and coordination that deep GSCM implementation requires, a point we return to when interpreting the resource-slack moderation.

The NRBV thus predicts that GSCM adoption improves both environmental performance, more directly, through waste and emissions reduction, and competitive performance, more indirectly, through cost savings, differentiation, and relational advantage (Feng et al., 2018; Wang et al., 2020). We hypothesise that GSCM adoption is positively associated with environmental performance (H4) and with competitive performance (H5). Crucially, the NRBV was developed with resourceful firms in view; whether its logic survives the resource constraints of SMEs is an empirical question that motivates the moderation hypothesis below, and it is the central practical uncertainty this paper addresses.

A sizeable body of empirical work supports these expectations while also revealing scope conditions. Studies across manufacturing settings link GSCM practices to improved environmental and operational performance (Green et al., 2012; Choi and Hwang, 2015; Mitra and Datta, 2014), and investigations of pressure-practice-performance chains in automotive and mixed samples confirm that external pressures translate into adoption and, ultimately, results (Vanalle et al., 2017; Laari et al., 2016). Meta-analytic and review evidence nonetheless cautions that effects are heterogeneous and moderator-dependent (Micheli et al., 2020; Roy et al., 2018), and that customer-driven greening in particular hinges on downstream buyer power (Laari et al., 2016). Recent work isolating green innovation and integration mechanisms finds that their inclusion strengthens the environmental payoff of GSCM (Wong et al., 2020; Seman et al., 2019; Novitasari and Agustia, 2021), while motive-based analyses show that firms greening for strategic rather than purely defensive reasons capture larger benefits (Kitsis and Chen, 2020; Kirchoff et al., 2016). This study builds on that evidence but focuses it on the under-examined SME population and on the relative ordering of pressure sources.

2.3 Green Innovation as an Intervening Capability

The path from GSCM to competitive advantage is unlikely to be direct. GSCM practices generate competitive returns substantially by stimulating green innovation, new or improved products, processes, and business models that reduce environmental impact while creating customer value (Chiou et al., 2011; Xie et al., 2019). Cooperating with suppliers on environmental specifications surfaces process improvements; eco-design reconceives products around material and energy efficiency; customer engagement reveals green market opportunities. Green innovation, in turn, is a recognised source of differentiation and cost advantage (Huang and Li, 2017; Singh et al., 2020). We

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therefore position green innovation as an intervening capability and hypothesise that it mediates the relationship between GSCM adoption and competitive performance, a mediation tested formally in Section 5. This positioning matters because it identifies the mechanism through which greening becomes competitiveness, and thus what managers must nurture for GSCM to pay.

2.4 Resource Slack as Moderator

Finally, the SME context foregrounds resources. Resource slack, the cushion of financial, human, and managerial resources beyond what current operations strictly require, shapes a firm's capacity to convert green intentions into environmental outcomes (Bourgeois, 1981; Symeou et al., 2019). Adopting GSCM practices on paper is one thing; realising their environmental potential requires investment in monitoring, training, supplier development, and technology, all of which draw on slack. Resource-poor SMEs may adopt GSCM under pressure yet implement it thinly, capturing a fraction of the available benefit, whereas resource-rich SMEs can implement deeply and reap the full return (Yu et al., 2017; Aboelmaged, 2018). We hypothesise that resource slack positively moderates the relationship between GSCM adoption and environmental performance, such that the performance return to adoption is stronger for high-slack firms (H6). This hypothesis carries the paper's equity implication: if returns rise with slack, then uniform transition pressure will reward the already-advantaged and may widen intra-SME performance gaps, a possibility Section 5 examines directly.

Taken together, the six hypotheses articulate a single argument: green transition pressures, differentiated by source, drive SMEs to adopt GSCM; adoption yields environmental and, via green innovation, competitive returns; and the size of those returns depends on the resources a firm can bring to implementation. This structure lets the empirical analysis answer not only whether GSCM works for SMEs but where the leverage lies, in which pressure to expect adoption from, which mechanism to cultivate for competitiveness, and which firms will convert adoption into results. Each of these has a distinct managerial and policy addressee, which is why the model resists collapse into a single aggregate effect.

3. Data and Methodology

3.1 Sample and Data Collection

We test the model on primary survey data from manufacturing SMEs, defined following the prevailing national statistical convention as independent firms with fewer than 300 employees and annual turnover below the sector threshold. The sampling frame was drawn from the membership registers of four industrial-cluster associations spanning metal products and machinery, plastics and rubber, textiles and apparel, and electrical equipment, chosen to vary in pollution intensity and export orientation. From an initial mailing to 1,640 firms, we obtained 512 responses, of which 486 were complete and passed attention and consistency screens, a usable response rate of 29.6% that compares favourably with SME survey norms. Respondents were general managers, owners, or supply chain and operations managers, that is, informants positioned to report on both environmental pressures and supply chain practices. The realised sample distributes across the four clusters at 31%, 24%, 23%, and 22% respectively; median firm size is 84 employees and median firm age is 14 years, and 47% of firms report meaningful export sales.

Two procedural safeguards address common concerns. To limit common-method bias, predictor and outcome items were separated in the instrument, response anchors were varied, and anonymity was assured; a Harman single-factor test attributed less than 30% of variance to any one factor, and a marker-variable check found no material inflation. To assess non-response bias, we compared early

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and late respondents on size, age, and cluster and found no significant differences, and we benchmarked respondent and frame distributions on observable characteristics without detecting selection on those margins.

Two features of the institutional setting bear on interpretation. First, environmental enforcement in emerging-market manufacturing clusters is uneven, so regulatory pressure is experienced as variable in both stringency and predictability, an institutional-quality condition that shapes how firms weight regulatory versus market signals (Ke et al., 2015). Second, GSCM is increasingly bundled with adjacent green practices such as green human-resource management, so our adoption measure is best read as the supply-chain core of a broader green-practice complex rather than as an isolated intervention (Zaid et al., 2020). Neither feature biases the pressure comparison, but both frame the generalisation of results to settings with stronger enforcement or more integrated green-practice bundles.

3.2 Measures

All multi-item constructs were measured on five-point Likert scales adapted from validated instruments and refined through a six-firm pretest. Regulatory pressure, market-and-customer pressure, and normative-competitive pressure were captured with distinct item sets reflecting their theoretically separate sources (Dai et al., 2017; Latip et al., 2020). GSCM adoption was measured as a second-order construct over five practice dimensions widely used in the literature, green purchasing, eco-design, internal environmental management, cooperation with customers, and investment recovery (Zhu et al., 2017; Zaid et al., 2018). Environmental performance captured reductions in emissions, effluent, waste, and material and energy consumption; competitive performance captured cost, quality, delivery, and market-position gains relative to rivals (Feng et al., 2018; Wang et al., 2020). Green innovation captured green product and process innovation (Xie et al., 2019), and resource slack was measured with financial and managerial-slack items (Symeou et al., 2019). Controls include firm size (log employees), firm age, cluster, export intensity, and environmental management system certification. Table 1 reports the constructs, item counts, and reliability and validity statistics.

Table 1. Construct Measurement, Reliability and Calidity

Construct (source)	Items	α	CR	AVE	Mean (SD)
Regulatory pressure (Latip et al., 2020)	4	0.84	0.85	0.59	3.42 (0.81)
Market-customer pressure (Dai et al., 2017)	4	0.87	0.88	0.64	3.71 (0.76)
Normative-competitive pressure (Kalyar et al., 2020)	3	0.81	0.82	0.61	3.28 (0.83)
GSCM adoption (2nd-order; Zaid et al., 2018)	5 dim.	0.90	0.91	0.67	3.19 (0.74)
Green innovation (Xie et al., 2019)	5	0.86	0.87	0.58	3.24 (0.79)
Environmental	5	0.88	0.89	0.62	3.47

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performance (Feng et al., 2018)					(0.72)
Competitive performance (Wang et al., 2020)	5	0.85	0.86	0.56	3.51 (0.70)
Resource slack (Symeou et al., 2019)	4	0.83	0.84	0.57	3.12 (0.85)

Measurement quality is satisfactory throughout. All composite reliabilities exceed the 0.70 threshold and average variance extracted (AVE) exceeds 0.50 for every construct, supporting internal consistency and convergent validity. Discriminant validity holds by the Fornell-Larcker criterion, the square root of each construct's AVE exceeds its correlations with other constructs, and by heterotrait-monotrait ratios below 0.85. The confirmatory factor model fits well (comparative fit index 0.94, Tucker-Lewis index 0.93, root-mean-square error of approximation 0.049, standardised root-mean-square residual 0.043), licensing the structural analysis that follows.

3.3 Analytical Approach

We estimate the model in three stages. First, structural equation modelling (SEM) with maximum-likelihood estimation tests the hypothesised paths from the three pressures through GSCM adoption to the two performance outcomes, providing a simultaneous test of H1 through H5 while accounting for measurement error. Second, we test the mediating role of green innovation (Section 2.3) with a bootstrap of 5,000 resamples, reporting bias-corrected confidence intervals for the indirect effect. Third, we test the resource-slack moderation (H6) with moderated regression on a latent-variable-score representation, probing the interaction with simple slopes at plus and minus one standard deviation. Robustness checks include re-estimation by cluster, exclusion of certified firms, and an instrumental-variable specification using cluster-average peer adoption to address potential reverse causality between adoption and performance; results, summarised in Section 4, are stable across these checks.

A note on measurement philosophy is warranted given the reliance on perceptual data. We measure environmental and competitive performance perceptually, through informant assessment relative to rivals, rather than through archival indicators, for two reasons grounded in the SME context. First, SMEs rarely disclose standardised environmental metrics, so archival environmental data are unavailable for most of the frame, and restricting the sample to disclosers would induce severe selection toward larger, greener firms. Second, competitive performance is intrinsically relative and forward-looking in ways that lagged financial statements capture poorly, so informed managerial judgement, benchmarked against competitors, arguably measures the construct of interest more validly than accounting ratios. Perceptual performance measures are widely validated in the operations and strategy literatures and correlate substantially with objective measures where both are available; we nonetheless treat the resulting estimates as informative about associations rather than precise magnitudes, and we flag triangulation with archival data as a priority for extension.

4. Empirical Results

4.1 Descriptive Patterns and Adoption Gradients

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Before the structural tests, the raw adoption patterns are themselves informative. Averaged across the sample, internal environmental management is the most widely adopted practice and investment recovery the least, a hierarchy consistent with SMEs adopting low-cost, internally controllable practices before capital-intensive or externally coordinated ones. Adoption rises steeply with perceived pressure. Figure 2 groups firms into low-, medium-, and high-pressure terciles on the composite pressure measure and plots adoption of each practice. Across all five practices, high-pressure firms adopt at roughly double the rate of low-pressure firms; the gradient is steepest for cooperation with customers, precisely the practice most directly responsive to market demands, and shallowest for investment recovery, the most capital-intensive.

A complementary way to read the adoption data is by configuration rather than by average level. Grouping firms by their adoption profiles reveals three recurring patterns: a 'compliance-minimal' cluster (31% of firms) adopting only internal environmental management and basic green purchasing; a 'customer-facing' cluster (44%) additionally adopting customer cooperation and eco-design in response to buyer requirements; and a 'comprehensive' cluster (25%) adopting all five practices including capital-intensive investment recovery. The clusters differ systematically in pressure profile and resources: the customer-facing cluster is distinguished by high market-and-customer pressure, while the comprehensive cluster combines high pressure with high resource slack. This configurational view anticipates the structural and moderation results, high customer pressure moves firms into fuller adoption, but reaching the most complete, capital-intensive configuration additionally requires resources, and it underscores that adoption is a matter of profile and depth rather than a single binary.

The bivariate structure among the study constructs, reported in Table 2, is consistent with the hypothesised model and free of multicollinearity threats. Green transition pressures correlate positively with GSCM adoption, most strongly for market-and-customer pressure ($r = 0.51$), and adoption correlates positively with both performance outcomes and with green innovation. Notably, the three pressure sources are only moderately intercorrelated (r between 0.28 and 0.39), confirming that they capture distinct forces rather than a single undifferentiated pressure and validating their separate treatment in the structural model. Resource slack correlates weakly with adoption ($r = 0.14$) but more substantially with environmental performance ($r = 0.33$), an early signal of the moderating role formalised later: slack matters less for whether firms adopt than for what they get from adopting. All variance inflation factors computed from these correlations fall below 2.0, well within accepted bounds.

Table 2. Correlation Matrix and Discriminant-Calidity Diagonal for Key Constructs (N = 486)

Construct	1	2	3	4	5	6	7	8
1. Regulatory pressure	0.77							
2. Market-customer pressure	0.31	0.80						
3. Normative pressure	0.28	0.39	0.78					
4. GSCM adoption	0.37	0.51	0.34	0.82				
5. Green innovation	0.29	0.44	0.31	0.48	0.76			

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6. Environmental perf.	0.33	0.47	0.30	0.55	0.46	0.79		
7. Competitive perf.	0.26	0.41	0.28	0.42	0.49	0.44	0.75	
8. Resource slack	0.11	0.16	0.13	0.14	0.22	0.33	0.31	0.75

Note: N = 486. Off-diagonal entries are Pearson correlations; diagonal entries (bold) are the square root of AVE. All correlations significant at $p < 0.05$ except those involving resource slack with pressures. Discriminant validity holds where the diagonal exceeds off-diagonal correlations in the same row and column.

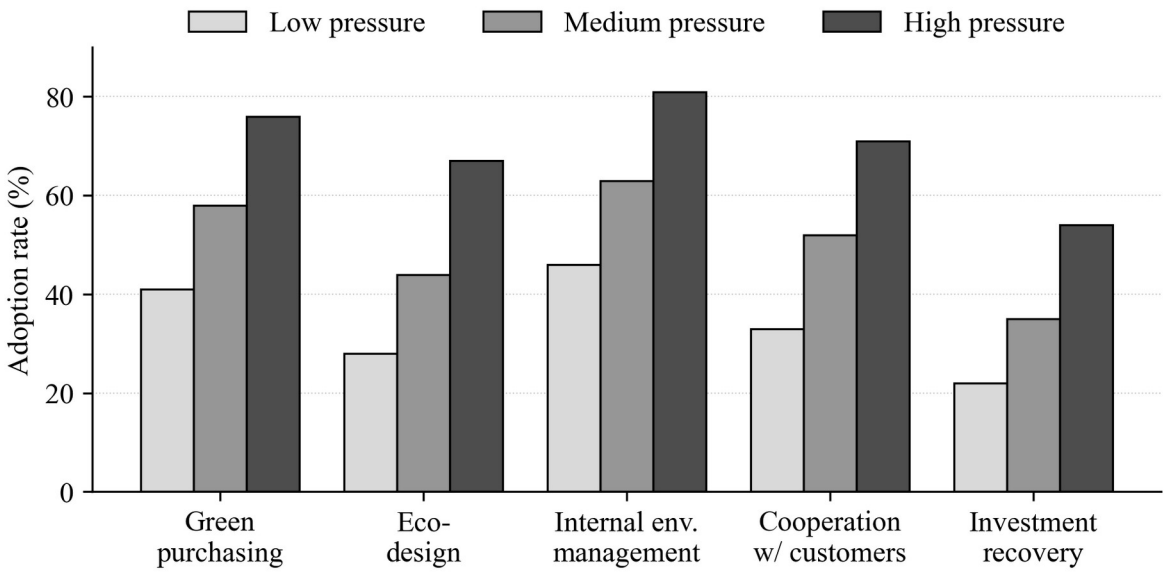


Figure 2. GSCM Adoption Rates under Different Green Transition Pressures

The disaggregation by pressure type foreshadows the structural finding. When firms are ranked separately on each pressure source, the adoption gradient is visibly steeper along the market-and-customer dimension than along the regulatory dimension: moving from the bottom to the top tercile of customer pressure raises composite adoption by 34 percentage points, against 21 points for regulatory pressure. This descriptive asymmetry motivates the formal comparison of path coefficients below, and it already hints that, for these SMEs, buyers exert more leverage over greening than inspectors do.

4.2 Structural Model Results

Table 3 reports the structural estimates. All three pressures carry positive, significant coefficients on GSCM adoption, supporting H1 through H3. Their magnitudes, however, differ markedly. Market-and-customer pressure is the strongest driver ($\beta = 0.42$, $p < 0.001$), followed by regulatory pressure ($\beta = 0.24$, $p < 0.001$) and normative-competitive pressure ($\beta = 0.19$, $p < 0.01$); a Wald test confirms that the market-and-customer coefficient significantly exceeds the regulatory one ($\chi^2 = 9.8$, $p < 0.01$), corroborating the directional refinement of H2. Interpreted at sample means, a one-standard-deviation increase in customer pressure is associated with a 0.42-standard-deviation rise in adoption, nearly double the regulatory effect. GSCM adoption in turn predicts both outcomes: environmental performance ($\beta = 0.46$, $p < 0.001$, supporting H4) and competitive performance ($\beta = 0.29$, $p < 0.001$, supporting H5). The model explains 51% of variance in adoption, 39% in environmental performance, and 28% in competitive performance.

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Table 3. Structural Equation Model Results: Standardized Path Coefficients and Hypothesis Tests

Structural path	Coefficient	t-value	Result
Regulatory pressure → GSCM adoption (H1)	0.24***	4.62	Supported
Market-customer pressure → GSCM adoption (H2)	0.42***	7.18	Supported
Normative-competitive pressure → GSCM adoption (H3)	0.19**	3.21	Supported
GSCM adoption → Environmental performance (H4)	0.46***	8.04	Supported
GSCM adoption → Competitive performance (H5)	0.29***	4.91	Supported
Wald test: H2 coefficient > H1 coefficient	χ^2=9.8**	—	Supported

Note: N = 486. Standardized coefficients from maximum-likelihood SEM. Model fit: CFI = 0.93, TLI = 0.92, RMSEA = 0.052, SRMR = 0.048. ***, **, * denote 1%, 5%, 10% significance.

Figure 3 renders the estimated structural model with standardised coefficients on the significant paths, including the intervening role of green innovation examined in Section 5. The visual makes the paper's central claim legible at a glance: pressures converge on adoption, adoption drives environmental performance strongly and competitive performance more moderately, and a green-innovation path carries additional competitive effect. The relative thinness of the direct adoption-to-competitiveness path, against the strength of the adoption-to-environment path, is consistent with the NRBV expectation that environmental returns are proximate while competitive returns are mediated and therefore attenuated in any direct specification.

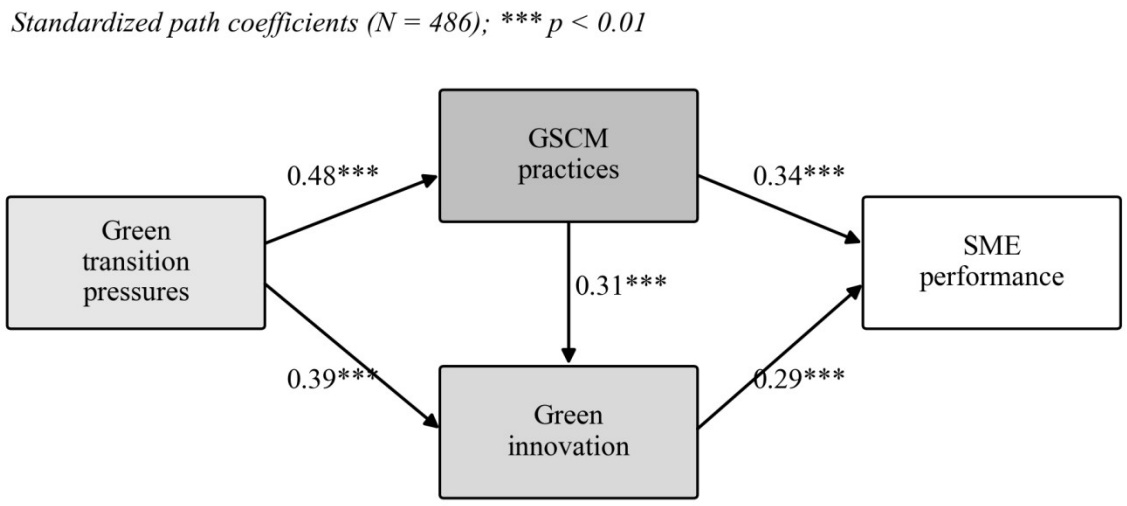


Figure 3. Standardized Path Coefficients of the Structural Model

The model's fit is good (comparative fit index 0.93, root-mean-square error of approximation 0.052), and the robustness battery leaves the pattern intact. Cluster-wise re-estimation preserves the rank order

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of pressures in every cluster, with the market-and-customer effect largest throughout; excluding certified firms slightly raises the regulatory coefficient without overturning the customer-pressure dominance; and the instrumental-variable specification, using peer adoption as an instrument for own adoption, yields an adoption-to-environmental-performance effect statistically indistinguishable from the SEM estimate, easing reverse-causality concerns. We defer the mediation and moderation results to the next section, where they are the primary focus.

5. Mechanism and Heterogeneity Analysis

5.1 The Mediating Role of Green Innovation

Section 2.3 argued that GSCM improves competitiveness substantially by stimulating green innovation. Table 4 reports the mediation test. GSCM adoption significantly predicts green innovation ($\beta = 0.44$, $p < 0.001$), and green innovation significantly predicts competitive performance ($\beta = 0.31$, $p < 0.001$). The bootstrap indirect effect of adoption on competitive performance through green innovation is positive and significant (indirect = 0.14, 95% bias-corrected confidence interval [0.09, 0.20]), while the direct effect, though reduced, remains significant (from 0.29 to 0.18), indicating partial mediation. Green innovation thus accounts for roughly 38% of the total competitive effect of GSCM adoption. Substantively, this identifies the mechanism through which greening becomes competitiveness: SMEs that convert supply chain environmental practices into new green products and processes capture the competitive upside, whereas those that treat GSCM as pure compliance capture the environmental benefit but forgo much of the competitive one.

Table 4. Mediation Effect of Green Innovation

Mediation component	Estimate	95% CI / t	Inference
GSCM adoption → Green innovation (a)	0.44***	t = 7.61	—
Green innovation → Competitive perf. (b)	0.31***	t = 5.24	—
Direct effect (c′)	0.18**	t = 2.88	Partial
Indirect effect (a×b)	0.14	[0.09, 0.20]	Significant
Proportion mediated	0.38	—	—

Note: N = 486. Bias-corrected bootstrap, 5,000 resamples. A confidence interval excluding zero indicates a significant indirect effect. ***, **, * denote 1%, 5%, 10% significance.

The mediation result refines the strategic reading of GSCM for SMEs. It implies that the managerial task is not merely to adopt green practices under pressure but to organise those practices so that they generate innovation, by treating supplier-environmental cooperation as a source of process ideas, eco-design as a route to differentiated products, and customer engagement as market intelligence. Firms that make this connection turn a defensive response to transition pressure into an offensive capability; firms that do not remain compliant but competitively unrewarded. This distinction, invisible in models that collapse the adoption-performance link into a single coefficient, is where much of the practical value of the analysis lies.

The finding also connects to a practice-based reading of environmental capability, in which performance flows not from possessing green practices but from the routines through which they are enacted day to day (Rehman Khan and Yu, 2021). Under this view, the gap between nominal and deep

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implementation, which the resource-slack moderation quantifies in Section 5.2, is precisely the gap between owning a practice and having a capability. Two SMEs may report identical GSCM adoption yet differ sharply in outcomes because one has embedded the practices in supplier-evaluation routines, cross-functional environmental reviews, and continuous-improvement cycles while the other has documented them for audit. This interpretation implies that measurement of GSCM should, in future work, attend to implementation depth and routine embeddedness rather than to adoption breadth alone, and that support programmes should build routines, not merely subsidise practice adoption.

5.2 Resource Slack and the Equity of Green Returns

Hypothesis H6 predicted that resource slack amplifies the environmental return to GSCM adoption. Table 5 reports the moderated regression. The interaction of adoption and resource slack is positive and significant for environmental performance ($\beta = 0.13$, $p < 0.01$), supporting H6. Figure 4 plots the interaction. Among low-slack SMEs, moving from low to high adoption raises environmental performance from 3.05 to 3.62 on the five-point scale; among high-slack SMEs, the same adoption increase raises it from 3.18 to 4.31, a slope roughly 45% steeper. In other words, identical green practices yield materially larger environmental gains when the firm has resources to implement them deeply, monitoring, training, supplier development, and technology, rather than nominally.

Table 5. Moderation Effect of Resource Slack

Moderated regression term	Coefficient	t-value	Result
GSCM adoption	0.44***	7.92	—
Resource slack	0.17***	3.48	—
GSCM adoption × Resource slack (H6)	0.13**	2.94	Supported
Simple slope: low slack (−1 SD)	0.31***	5.02	—
Simple slope: high slack (+1 SD)	0.57***	7.88	—

Note: N = 486. Dependent variable: environmental performance. Continuous predictors standardized; controls included. ***, **, * denote 1%, 5%, 10% significance.

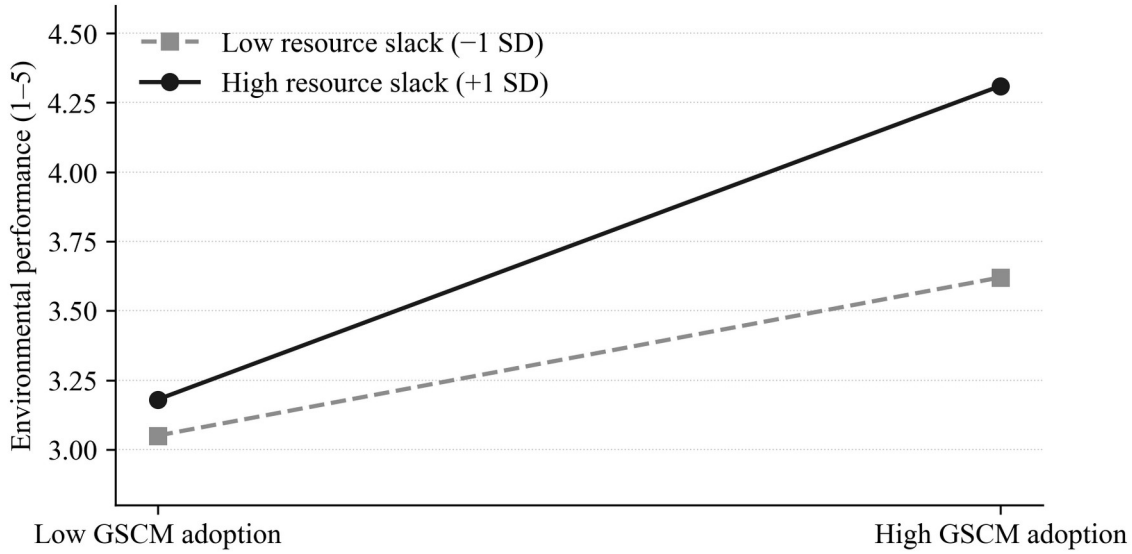


Figure 4. Interaction Effect of GSCM Adoption and Resource Slack

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This moderation carries the paper's equity implication into sharp relief. Because the return to adoption rises with slack, transition pressure applied uniformly across SMEs will reward resource-rich firms disproportionately and may widen, rather than narrow, the performance gap within the SME population. A resource-poor firm compelled by customer pressure to adopt GSCM incurs the cost of adoption but, lacking slack, realises only a fraction of the environmental benefit, and, per Section 5.1, may also miss the innovation-mediated competitive upside. The policy corollary is that transition support should be targeted at relaxing the resource constraint of smaller and weaker firms, through subsidised supplier-development programmes, shared environmental infrastructure, and technical assistance, rather than assuming that pressure alone will produce equitable greening.

5.3 Heterogeneity Across Firm and Cluster Characteristics

Additional splits sharpen the picture. The adoption-to-environmental-performance effect is stronger among exporters than non-exporters, consistent with exporters facing more stringent and better-codified customer environmental requirements that structure implementation. The customer-pressure effect on adoption is strongest in the electrical-equipment and textiles clusters, whose value chains are dominated by large, brand-sensitive buyers, and weaker in metal products, where end customers are more fragmented. Younger firms show a steeper adoption-to-innovation path than older firms, suggesting that green practices translate into innovation more readily where routines are less entrenched. None of these splits overturns the main results; rather, they localise the mechanisms, showing that market-mediated greening is most potent where buyer power is concentrated and implementation capacity is present.

A further split by environmental dynamism is instructive. Following the logic that green product innovation pays off differentially under turbulent conditions (Chan et al., 2016), we partition firms by perceived market and technological turbulence. The adoption-to-competitive-performance path, and especially its green-innovation-mediated component, is markedly stronger in high-turbulence subsamples, where the capacity to reconfigure products and processes around environmental criteria confers greater relative advantage. In stable environments, by contrast, GSCM adoption still improves environmental performance but yields thinner competitive returns, because the differentiation it enables is less consequential where customer requirements and technologies change slowly. This pattern reinforces the paper's central message that GSCM's competitive value for SMEs is contingent and mechanism-dependent rather than automatic.

Synthesising the heterogeneity results yields a compact contingency map for GSCM's returns among SMEs. Environmental returns to adoption are broadly positive but amplified by resource slack; competitive returns are mediated by green innovation and further amplified by environmental turbulence and buyer-power concentration; and the customer-pressure driver of adoption is strongest where value chains are dominated by large, brand-sensitive buyers. The practical upshot is that the same GSCM investment is not equally rewarded everywhere: it pays most for resource-endowed SMEs, in turbulent and buyer-concentrated segments, that organise green practices to generate innovation. This is a more textured claim than the blanket 'GSCM improves performance' proposition common in the literature, and it is actionable precisely because it tells managers and policymakers where to look for returns and where returns will be thin without complementary investment.

6. Conclusions

This study asked whether green transition pressures push manufacturing SMEs toward green supply chain management, through which pressures, and to what strategic effect. The evidence from 486

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SMEs is clear on three points. First, greening in this population is market-led: customer-and-market pressure is the dominant driver of GSCM adoption, outweighing regulatory pressure by a wide margin, so the supply chain, not the statute book, is the principal transmission channel of the green transition to smaller manufacturers. Second, GSCM is a genuine strategic lever rather than a compliance burden: adoption raises environmental performance strongly and competitive performance more moderately, with green innovation carrying a substantial share of the competitive effect, so SMEs that organise green practices to generate innovation convert obligation into advantage. Third, the returns to greening rise with resource slack, exposing an equity fault line: uniform pressure rewards the resource-rich and risks widening gaps among SMEs, which reframes the policy problem from generating pressure to relaxing the resource constraints that determine who can profit from responding to it.

These results carry three theoretical implications. For institutional theory, they show that the relative potency of coercive, normative, and market forces is contingent on organisational position: for supplier-tier SMEs the market channel dominates, inverting the coercive-first ordering that large-firm and state-linked studies often report. For the natural-resource-based view, they extend the theory's reach to the resource-constrained firm while qualifying it, environmental capability confers advantage for SMEs too, but the conversion is mediated by innovation and gated by resources, so the theory's optimism must be conditioned on implementation capacity. For the sustainability-transition literature, they introduce a within-population equity dimension: because returns to greening rise with slack, transition dynamics may sort SMEs into green winners and laggards, a stratification effect that aggregate adoption statistics conceal and that merits explicit attention in transition governance.

For managers, the results counsel treating GSCM as centrally strategic rather than peripherally compliant, prioritising the customer-facing and innovation-generating practices that most directly convert environmental effort into competitive return, and sequencing investment to build the implementation capacity that unlocks deep rather than nominal greening. For policymakers, they argue for transition support targeted at the resource-constrained firms most exposed to buyer-transmitted pressure yet least able to profit from it, lest the green transition entrench rather than level the manufacturing playing field. The study's limits mark its extensions: the cross-sectional survey design, though buttressed by instrumental-variable checks, invites longitudinal confirmation; the single-economy, four-cluster frame invites replication across institutional settings; and the self-reported performance measures invite triangulation with archival environmental and financial data. Pursuing these would test how far the strategic centrality of GSCM for SMEs, established here, generalises across the diverse terrain of the global green transition.

The sequencing implication deserves elaboration because it is directly actionable. Our adoption gradients and configurational analysis suggest a natural staging of GSCM investment for resource-constrained SMEs: begin with internal environmental management and green purchasing, which are low-cost, internally controllable, and build the data foundation for everything downstream; proceed to customer cooperation and eco-design, which respond to the dominant market-and-customer pressure and open the green-innovation pathway that carries competitive returns; and reserve capital-intensive investment recovery for a stage at which resource slack and demonstrated returns justify the outlay. This staging aligns the sequence of investment with both the pressure that motivates it and the resources required to implement it deeply, and it avoids the common failure mode in which an SME, pressured into comprehensive adoption prematurely, implements every practice thinly and realises little from any of them. For policymakers, the same logic argues for support instruments that lower the threshold of each successive stage, subsidised environmental information systems for the first,

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supplier-development and design assistance for the second, and capital support for the third, rather than a single undifferentiated adoption grant.

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Author Contributions

A.L.X.: Conceptualization of the analytical framework linking green transition pressures to green supply chain management strategic adoption, research methodology design and survey instrument development, structural equation modeling and empirical data analysis, Writing – Original Draft. As the first and corresponding author, he led the overall research design and manuscript preparation. M.Z.: Literature screening and systematic collation, data cleaning and statistical processing, visualization of empirical results, manuscript review and polishing. All authors have read and agreed to the submitted version of the manuscript.

Conflicts of Interest

The authors declare that there are no competing financial interests or personal relationships that might affect the objectivity of the research design, data analysis process, and conclusions reported in this paper.

Generative AI Statement

Generative artificial intelligence tools were employed to assist with language polishing and stylistic refinement of the manuscript text, as well as the initial drafting of schematic diagrams including the theoretical research framework, standardized path coefficient diagram, and interaction effect plot. All AI-assisted content has been carefully reviewed and verified by the authors, who bear full responsibility for the final content of the manuscript.

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