

Green Supply Chain Management Practices for Carbon Emission Reduction in Manufacturing SMEs Through Sequential Environmental Capability Development

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Abstract

Manufacturing small and medium-sized enterprises in China face growing regulatory and market pressure to reduce carbon emissions while maintaining competitiveness. Although many firms have adopted green supply chain management practices (GSCMP), they often lack the internal capabilities required to convert these initiatives into measurable carbon emission reductions. Previous research has primarily examined green supply chain management and carbon emission reduction independently, providing limited understanding of the sequential capability-building process involving circular economy practices, green innovation, and environmental management practices. Moreover, the moderating role of top management environmental commitment has received limited empirical attention. Drawing upon the Natural Resource-Based View, this study explains how GSCMP are transformed into environmental performance through the development of internal organizational capabilities. Survey data were collected from 343 manufacturing SMEs in China and analyzed using variance-based structural equation modeling in ADANCO to examine direct, sequential mediation, and moderation effects. The findings indicate that GSCMP positively influence circular economy practices and green innovation, while circular economy practices further enhance green innovation. Green innovation strengthens environmental management practices, which significantly improve carbon emission reduction. Furthermore, circular economy practices, green innovation, and environmental management practices sequentially mediate the relationship between GSCMP and carbon emission reduction. Top management environmental commitment also strengthens the positive relationship between environmental management practices and carbon emission reduction. This study extends the Natural Resource-Based View by identifying a sequential capability-building mechanism linking GSCMP with carbon emission reduction. It also provides manufacturing SME managers with a practical roadmap for prioritizing circular economy practices, green innovation, leadership commitment, and environmental management to achieve more effective carbon reduction.

Introduction

Carbon emissions from industry contribute a large amount to global greenhouse gas emissions and climate change has emerged as one of the greatest challenges facing industrial economies (Zhou et al., 2024). China's national dual carbon strategy aims to reach peak carbon emissions in the not too distant future – by 2030 – and achieve carbon neutrality by 2060, with China being the world's largest manufacturing economy (Zhan et al., 2024). Manufacturing small and medium enterprises (SMEs) are an essential part of China's manufacturing industry chain and production, but their total energy consumption and carbon emission are also significant (Ma et al., 2025). While in the recent years, the governments are imposing increasingly strict environmental laws and the market is demanding more sustainable business models for firms, there are still various financial, technical, and managerial challenges that many SMEs face when implementing green supply chain initiatives effectively (Liu et al., 2024). The challenges are associated with the lack of environmental outcomes and lack of transformation of environmental commitments into operational capabilities in the manufacturing SMEs, which emphasizes the need for research to explain how green supply chain initiatives can lead to measurable environmental outcomes.

Recent studies have confirmed that Green Supply Chain Management (GSCM) practices enhances the environmental and organizational performance in the manufacturing industries (Ostic et al., 2025; Eltayeb, 2025). Green purchasing allows companies to work with companies which have environmental consciousness and order materials that are environmentally-friendly, and green manufacturing minimizes waste, resource use and pollution from manufacturing (Xiong et al., 2025). In the same way, green distribution promotes logistics efficiency by optimizing transport systems, using eco-friendly packaging and minimizing fuel use (Rao & Holt, 2005). These

practices combine to better operational efficiency, environmental performance, competitive advantage, and financial returns. Previous research also has demonstrated that companies with extensive GSCM activities obtain gains in terms of sustainability performance from the increase of GSCM's resource efficiency and the organization's relationship with stakeholders (Ning et al., 2025). This has caused GSCM to shift from being an 'environmental compliance' approach to a strategic capability to maintain long-term competitiveness and meet rising expectations for the environment along global manufacturing supply chains.

Although significant progress has been made, the full impact of GSCM practices on carbon emission reduction remains unknown. Previous studies have mainly focused on the direct impacts of GSCM on the environmental, financial or operational performance and have neglected to investigate the internal organizational mechanisms that enable environmental improvements to be achieved (Xin, 2024). In particular, there was limited focus on studying the synergistic effects of circular economy practices, green innovation and environmental management practices as complementary capabilities which sequentially link external supply chain practices and measurable carbon reduction effects (Guo & Luo, 2026). The existing research tends to focus on these constructs alone or on limited number of mediators and provides a partial explanation of the development of organizational capability (Xin, 2024). This restriction is especially pronounced in the manufacturing sector, especially SMEs, where resource limitations impose a need for SMEs to maximize their investments in the environment (Li et al., 2024). Managers without knowledge of the sequential process of building capacity may not be able to identify which of the initiatives in their organizations can be done first to make a significant contribution toward reducing their carbon emissions (Wen et al., 2025). Thus, a thorough study on the relationship between GSCM activities and carbon emission reduction is still needed, especially for Chinese manufacturing SMEs.

Theoretically, other critical issues are not addressed. First, the potential for a mechanism gap exists because there is limited prior research that has focused on the entire sequential mediation process between GSCM practices and carbon emission reduction through circular economy practices, green innovation, and environmental management practices (Ai et al., 2024; Ma et al., 2025; Ning et al., 2025). Second, there is a context gap in that much of the current evidence comes from large manufacturing organisations that have more financial and technological resources available, while SMEs have significantly different resource constraints and structure (Awewomom et al., 2024). Thirdly, a lack of knowledge is still demonstrated in the literature about the boundary conditions under which environmental management practices produce greater environmental results. Specifically, the moderating role of top management environmental commitment has not been sufficiently investigated in empirical research, although it is important for allocating resources, assigning environmental priorities, building organizational legitimacy and for successful implementation of sustainability initiatives (Zhu et al., 2025). The gaps in the theory can be filled by providing a more comprehensive explanation for organizational environmental capability development in the context of the Natural Resource-Based View.

Based on this, this study explores the sequential development of circular economy practices, green innovation and environmental management practices of manufacturing SMEs in China in the process of reducing carbon emissions and how GSCMP affect the carbon emission reduction. Based on the Natural Resource Based View (Hart, 1995), the study additionally investigates whether the strength of the top management environmental commitment is a moderator between environmental management practices and carbon emission reduction. In particular, the research questions are: Do GSCM practices encourage practices of circular economy and green innovation? Are circular economy practices pro-green innovations? Do green innovations support good environmental management? Are the environmental management practices helpful in reducing carbon emission? Do the individual and sequential mediation mechanisms between the relationships exist in the area of circular

economy practices, green innovation and environmental management practices? Lastly, do good environmental management practices (that lowers carbon emissions) are enhanced by top management environmental commitment?

This study has four key contributions to the sustainability and supply chain management literature. First, it extends the Natural Resource-Based View by proposing and empirically testing a comprehensive sequential mediation framework to explain the transformation of externally oriented GSCM practices in the creation of internal environmental capabilities, which in turn leads to carbon emission reductions. Second, it pinpoints the complementarities that exist between the various activities of the circular economy, green innovation and environmental management that together contribute to the decarbonisation of the organisation, as opposed to being seen as separate sustainability projects. Third, the study includes top management environmental commitment as an important boundary condition that accounts for the fact that environmental management practices result in better environmental outcomes when top management shows more environmental commitment. Last but not least, the results offer practical suggestions for developing capabilities for manufacturing SME managers, including the priorities for enhancing their capability to utilize resources, to improve environmental performance and to underpin China's dual carbon goals, and to strengthen long-term organizational competitiveness.

Literature Review

Conceptual foundation

Green Supply Chain Management Practices

GSCMP are the systematic incorporation of environmental concerns in the activities of SC, from product design, green purchasing, manufacturing, distribution and end of life management, aiming to reduce environmental impacts while keeping operation and economic performance (Ning et al., 2025). The most prolific definition came from Srivastava 2007 (Zhu & Sarkis, 2007) that defined GSCM as incorporating environmental thinking in the supply chain management process of sourcing, production, delivery, and product recovery. In empirical research, the three main components of GSCMP are green purchasing, green manufacturing, and green distribution, which are upstream, in-house, and downstream environmental activities, respectively (Guo & Luo, 2026). These dimensions are also used in recent SSCI studies and have proven to be important for environmental and organisational performance, as demonstrated by (Testa & Iraldo, 2010) and (Wen et al., 2025). The main conceptual debate is whether GSCMP is a more environmental construct, or as part of a larger sustainable supply chain management that also includes social and economic aspects (Zhu & Sarkis, 2004). There have been recent evidences that support the idea of maintaining conceptual difference but acknowledging near theoretical similarity.

Circular Economy Practices

Circular economy practices are organizational activities that maximize the value of products, materials and resources by extending the life cycles of products through reuse, remanufacturing, recovery, recycling and regenerative design (Ye & Zhang, 2025). The conceptual basis is drawn from the circular economy framework outlined by the Ellen MacArthur Foundation (2013) and focuses on restorative industrial systems which are

engineered to never create waste. Today, circular economy practices are often broken down into three categories: corporate asset management and recovery, eco design and internal environmental management (Ai et al., 2024; Zhu et al., 2025). The research on urban and rural regions on circular economy is vast developed but semi-urban regions are under-discussed (Arora, 2026). Corporate asset management emphasizes on the recovery of resources and the extension of product life; eco design emphasizes on minimizing environmental impacts in the process of product development, and internal environmental management institutionalizes the idea of circular thinking in organizational processes (Ostic et al., 2025). These dimensions have been confirmed as the key dimensions of resource efficiency and sustainable competitiveness by recent SSCI studies (Geissdoerfer et al., 2022; Kristoffersen et al., 2023) (Geissdoerfer et al., 2017; Kirchherr et al., 2017). However, the conceptual distinction between CIRCULAR ECONOMY PRACTICES and green supply chain management is still discussed, as both are focused on an environmental sustainable approach, but CIRCULAR ECONOMY PRACTICES goes beyond the principle of 'pollution prevention and prevention of waste' by emphasizing restorative resource loops (Govindan & Hasanagic, 2018).

Green Innovation

Green innovation is the design and application of environmentally friendly solutions, including products, processes, technologies and managerial solutions, which generate economic value whilst minimising the negative impacts on the environment (Xiong et al., 2025). According to the original conceptualisation, green innovation would be innovations that are associated with products and processes which are relevant to environmental protection, pollution prevention, energy saving, recycling and waste reduction, which is given by (Chen et al., 2006). Two complementary dimensions are outlined in contemporary literature: green process innovation, that is the improvement of the production efficiency with cleaner technologies; and green product innovation, that is the development of environmentally preferable products along their life cycle (Xie et al., 2019; Alqahtani, 2025). Green innovation is frequently highlighted in recent SSCI studies as being an important strategic capability that connects sustainability efforts with competitive advantage and environmental performance (Chiou et al., 2011; Li et al., 2018). While there is significant conceptual consensus, researchers are still debating whether organizational, marketing and managerial innovations can be included in the construct or whether they are a separate category of environmental innovation.

Environmental Management Practices

Environmental management practices are defined as formal policies, systems, procedures and activities that are carried out within an organization to minimize environmental impacts, comply with the regulatory requirements and continually improve the environment (Awewomom et al., 2024; Du et al., 2025). This idea came from a body of literature describing the environmental management system, specifically ISO 14001, developed by the International Organization for Standardization, which sets out standards for systematic environmental management planning, implementation, monitoring, and continuous improvement (Li et al., 2024). Empirical studies suggest that the current research conceptualisation of environmental management practices include environmental planning, employee involvement, pollution prevention, monitoring systems and compliance mechanisms (Ning et al., 2025). The recent SSCI evidence shows that well-designed environmental management practices enhance not only the environmental performance, operational efficiency and organizational sustainability, but also green innovation potential (Awewomom et al., 2024; Sarkis et al., 2010). Researchers still

contrast environmental management practices versus GSCMP as EMP focuses on the internal governance of the organization while GSCMP takes environmental management beyond the boundaries of the organization.

Carbon Emission Reduction

Carbon emission reduction involves proactive organizational measures which lead to a reduction in greenhouse gas emissions produced by the organisation during its production, logistics, energy usage and other activities (Zhou et al., 2024). It draws on international climate governance set up under the United Nations Framework Convention on Climate Change and the carbon management literature, which has focused on the decarbonisation of organisations (Ma et al., 2025). This is a contemporary study that operationalizes carbon emission reduction as measurable reduction in carbon dioxide emissions by implementing cleaner technologies, renewable energy, energy efficiency, process optimization, and sustainable logistics (Peng et al., 2024). Reducing carbon emissions has been a recurring theme in the latest SSCI studies, which emphasise it as a significant environmental performance indicator for green supply chain management, the circular economy and green innovation (Wen et al., 2025; Al Qussair et al., 2026). An ongoing conceptual debate is whether carbon emission reduction should be considered as an organizational competence in its own right or as an environmental performance measure in the light of other sustainability management measures (Zhan et al., 2024). The latter view is the one that is most widely accepted in the existing literature.

Top Management Environmental Commitment

Top management environmental commitment is defined as the behaviours of the top management that set the tone for the organization in terms of leadership, resource allocation, environmental strategies and active support for environmental initiative (Chiou et al., 2011)s. The construct is conceptually based on upper echelon theory that (Darnall et al., 2008) stated that organizational decisions and performance is determined by executive values and strategic priorities. This view was later expanded in the environmental management literature to include the importance of executive commitment as an important precursor for the implementation of environmental strategies (Xin, 2024). The adoption of green supply chain management, circular economy, green innovation and environmental performance is closely interlinked and is found to require top management environmental commitment as one of the key organizational capabilities (Du et al., 2025), which is identified as one of the key organizational capabilities in recent SSCI studies. While everyone agrees it is an important part of business, there are still arguments on whether it is a part of the leadership or a culture or a strategic resource (Delmas & Pekovic, 2013). A great deal of modern studies consider it as a strategic leadership ability, one that supports organization broad environmental modification.

Underpinning theory

The Natural Resource Based View (NRBV) is the most suitable theory to serve as a basis for research in the present study as it explains how organizational resources and capabilities based on environmental awareness gives a sustainable competitive and environmental advantage. The NRBV was first proposed by (Hart, 1995), who contended that a company can gain long term competitive advantage by establishing the ability to solve environmental problems by pollution prevention, product stewardship and sustainable development. The NRBV sees environmental initiatives not as a regulatory requirement, but as a valuable, scarce, hard-to-imitate and organizationally integrated strategic resource, that can support both ecological and organizational success.

One of the underlying principles of the NRBV is that it is not the external environment that creates high performance. Rather, organizations are able to generate sustainable value by embedding the external practice in the organization's capabilities, which makes it more efficient in using resources, innovate more, and manage the environment more effectively. Thus, companies that successfully embed environmental programs into their day-to-day activities cultivate distinctive competences that are difficult for other companies to emulate. In this theory, capability development is the key mechanism for bringing environmental strategies to fruition for measurable outcomes in the organization.

In the current model, GSCMP are external oriented strategic practices that start environmental transformation of the organization by green purchasing, green manufacturing and green distribution. These practices drive the internal development of organisations' competences, including those of circular economy practices, green innovation and environmental management practice. Resource-based circular economy practices promote resource recycling and waste recovery, green innovations enable environmentally sustainable products and production processes and environmental management practices strengthen institutionalisation of environmental governance and operational control. The complementary attributes provide a framework to help organisations use resources most effectively, minimise pollution, increase operational efficiency and create carbon emission reduction as a core environmental performance metric. Therefore, the carbon emission reduction is explained as being the result of the successful implementation of the capabilities devised by the company itself for environmental purposes, which are derived from the initiatives carried out from the outside by the company in the context of the green supply chain.

The NRBV also offers a solid theoretical basis for the moderating effect of top management environmental commitment. The theory acknowledges leadership commitment as a valuable resource of an organisation and considers it to be a factor which influences whether the environmental capabilities are effectively developed and utilised. Senior management affects strategic agenda through financial resource allocation, setting environmental goals, organizational learning, and cross functional collaboration. On this ground, it is possible to realize the GSCMP as effective practices of circular economy, green innovation and environmental management, and such a possibility is greater for organizations that are better equipped in the environmental commitment of the top management. Conversely, companies with low-level support from the top have a lower probability of institutionalizing environmental capabilities although they are practicing similar green supply chain initiatives. Hence, the NRBV thoroughly captures the dynamic transition from external environmental practices to internal capability development and then to better environmental performance, with special emphasis on the strategic resource of the top management commitment to the environment, which enhances capability deployment throughout the model.

Hypothesis Development

The previous research has consistently shown that GSCMP encourage the adoption of circular economy practices through resource efficiency, waste minimization, sustainable sourcing and recovery of products throughout supply chains (Green Jr et al., 2012; Guo & Luo, 2026). The more organizations that have adopted green purchasing, green manufacturing and green distribution, the more likely they are to embed recycling, remanufacturing, eco design and resource recovery into their processes (Ning et al., 2025; Wen et al., 2025). The Natural Resource-Based View sees environmentally oriented supply chain practices as strategic resources that can drive the creation of valuable in-house capabilities (Testa & Iraldo, 2010). In this way, green supply chain management establishes the

organizational basis for the implementation of circular economy initiatives focused on improving the use of resources (Xiong et al., 2025). Therefore, the following hypothesis is proposed:

H1a

GSCMP positively influence circular economy practices.

Practical experiences have shown that organizations that have implemented GSCMP have higher rates of green innovation as environmental cooperation with suppliers and customers has led to the exchange of knowledge, cleaner technologies, and product development that are more environmentally friendly (Li et al., 2018; Ye & Zhang, 2025). The Natural Resource Based View of environmental practices argues that by enabling firms to build superior organizational capabilities, environmental practices can lead to sustainable competitive advantages among the firm (Ai et al., 2024). Green purchasing, manufacturing and distribution processes provide companies with environmental learning and green experience, which encourage green process and product innovation (Chiou et al., 2011; Xiong et al., 2025). Thus, it can be predicted that organizations that have a more robust GSCMP will exhibit more green innovation power. Therefore, the following hypothesis is proposed:

H1b

GSCMP positively influence green innovation.

The current literature indicates that circular economy principles stimulate companies to create innovativeness of their products and production processes by focusing on sustainability, waste reduction, extending product life cycle and closed loop material flows (Ostic et al., 2025). Firms can benefit from the opportunities offered by practices like eco design, resource recovery, and internal environmental management, which can lead to the implementation of environmentally sustainable technologies and operational enhancements (Geissdoerfer et al., 2017; Kirchherr et al., 2017). In the NRBV, practices of circular economy are seen as strategic organizational skills that promote the development of valuable environmental knowledge and innovation (Masi et al., 2017). Therefore, the companies that are successfully implementing a circular economy are more likely to be able to create green products and clean production processes. Therefore, the following hypothesis is proposed:

H2

Circular economy practices positively influence green innovation.

Previous research has shown that firms that invest in green innovation can more easily reinforce their environmental management practices through introducing cleaner technologies, environmentally friendly production processes, and sustainable organizational routines (Awewomom et al., 2024). The Natural Resource-Based View focuses on the fact that green innovation helps to build a firm's internal competence through the creation of new environmental knowledge and organizational learning (Ning et al., 2025). These innovations are part of the structured environmental policies, monitoring systems and continuous improvement systems that are integral to good environmental management (Li et al., 2024). Hence, the more capable an organization is at becoming green, the more comprehensive its environmental management will be. Hence, the following hypothesis is proposed:

H3

Green innovation positively influences environmental management practices.

The results from extensive empirical studies suggest that systematic environmental planning, pollution prevention, resource monitoring, energy efficiency, and continuous process improvement are the elements of effective environmental management practices that can significantly lower organizational carbon emissions (Darnall et al., 2008; Liu et al., 2025). The NRBV suggests that the firms with a sound environmental management system can make efficient use of the resources and reduce the impact on the environment (Zhan et al., 2024). Organizations can use formal environmental policies, environmental performance monitoring and operational control to determine the sources of pollution and take action to reduce emissions (Liu et al., 2024). This, in turn, will lead to better environmental management practices, which will in turn support firms' capacity for significant carbon emission reductions and better overall environmental performance (Ma et al., 2025). Therefore, the following hypothesis is proposed:

H4

Environmental management practices positively influence carbon emission reduction.

Research on previous GSCMP suggests that these initiatives can drive organizations to adopt CE practices, which in turn can stimulate green product and process innovation (Geissdoerfer et al., 2017; Genovese et al., 2017). According to the Natural Resource Based View, environmental efforts which are external focus resources, are then turned into resources within the organisation through the development of internal resources, and then into new ideas and products (Ye & Zhang, 2025; Zhu et al., 2025). The operational basis of the implementation of circular economy is provided by GSCM, and sustainable utilization of resources and environmental knowledge is ensured by the practices of circular economy (Kirchherr et al., 2017). Therefore, circular economy practices are anticipated to pass positive message of GSCMP to green innovation. Therefore, the following hypothesis is proposed:

H5a

Circular economy practices mediate the relationship between GSCMP and green innovation.

Empirical evidence has shown that circular economy practices are associated with green innovation such as cleaner technologies, eco design and sustainable production systems, while green innovation is linked to environmental management by means of better environmental policies, environmental management controls and ongoing environmental improvement (Ai et al., 2024; Chiou et al., 2011). The NRBV states that organizational capabilities grow over time: Activity based on resource efficiency leads to innovation capabilities which in turn are institutionalized within formal environmental management activity (Ostic et al., 2025; Xie et al., 2019). Therefore, green innovation is the mechanism by which circular economy practices increase the ability of the organization in the environmental management process. Hence the following hypothesis is suggested:

H5b

Green innovation mediates the relationship between circular economy practices and environmental management practices.

The importance of reducing carbon emissions has gained momentum in recent sustainability research, and the process of reducing carbon emissions is one in which a series of connected organizational capabilities are required, rather than one environmental effort (Ai et al., 2024). GSCMP incentivize companies to implement

circular economy, thereby fostering green innovation and, eventually, bolstering environmental management systems directly leading to carbon emissions reduction (Liu et al., 2024). According to the Natural Resource Based View (NRBV) advantage to the organization comes from a combination of external environmental practices and internal capabilities (Wang, 2025). Thus, GSCMP is considered to affect the reduction of carbon emissions indirectly via a chain of events that include the development of circular economy practices, green innovations, and environmental management practices. Based on this, the following hypothesis is proposed:

H6

Circular economy practices, green innovation, and environmental management practices sequentially mediate the relationship between GSCMP and carbon emission reduction.

Previous studies have shown that high-level environmental commitment in the organization can make its environmental initiatives more effective, as it offers strategic guidance, funds, environmental governance, and accountability for environmental goals (Daily & Huang, 2001; Farooque et al., 2019). The NRB value approach sees managerial commitment as a valuable resource that is used to deploy environmental capability more effectively (Green Jr et al., 2012). When top management is more environmentally interested, organizations invest more in environmental technologies, have more stringent monitoring systems, have stronger environmental policy and improve organizational legitimacy with stakeholders (Lee, 2012; Peng et al., 2024). Such actions will improve the effectiveness of environmental management actions toward carbon emission reduction (Zhan et al., 2024). On the other hand, if managers are not committed, they may have less access to resources and thus less effectiveness in implementing environmental programs. Hence the following hypothesis is forwarded:

H7

Top management environmental commitment positively moderates the relationship between environmental management practices and carbon emission reduction, such that the positive effect of environmental management practices on carbon emission reduction is stronger when top management environmental commitment is high.

Theoretical framework

The NRBV was used to develop the theoretical framework for this research (see Fig. 1). The framework suggests that Green Supply Chain Management (GSCM) Practices is the exogenous construct that starts the process of the development of environmental capability in an organization. Specifically, the hypothesis of this study is that GSCM practices directly affect Circular Economy Practices (H1a) and Green Innovation (H1b); and Circular Economy Practices directly affect Green Innovation (H2). Green Innovation is then expected to boost Environmental Management Practices (H3) which will eventually lead to Carbon Emission Reduction as the endogenous outcome of the study (H4). Additionally, indirect mechanisms are included in the framework, as suggested by the role of Circular Economy Practices in the mediating relationships between GSCM Practices and Green Innovation, and that of Green Innovation in the mediating relationships between Circular Economy Practices and Environmental Management Practices. Moreover, the three constructs mediate the relationship among the GSCM Practices and Carbon Emission Reduction one after another. Finally, Top Management Environmental Commitment is suggested as a moderating variable between Environmental Management Practices and Carbon Emission Reduction (H7) to strengthen the positive association between Environmental Management Practices and Carbon Emission Reduction, indicating that the effectiveness of environmental management practices in reducing carbon emission is reinforced by the managerial commitment.

Methodology

Research design

The study adopted a quantitative cross sectional survey design to explore the relationships between GSCMP, circular economy practices, green innovation, environmental management practices, carbon emission reduction and top management environmental commitment of manufacturing SMEs in China. The cross sectional design is suitable because it allows the examination of multiple direct, mediating and moderating relationships within a comprehensive variance based structural model. This is the approach that is widely used to test theories about organizational abilities and sustainability practices. Data collection was subject to a number of procedural remedies to minimize potential biases even though cross sectional data does not allow for causal inference. Future research is encouraged to use a longitudinal or a time lagged research design to get better evidence of how organizational environmental capabilities evolve in time and how they impact carbon emission reduction.

Sample

The study population consisted of manufacturing small and medium-sized enterprises (SMEs) in various industrial sectors in China, such as machinery, electronics, automotive components, chemicals, textiles, food processing, metal manufacturing, etc. Industries were chosen due to their large share of industrial production and environmental emissions and due to the fact that they are under growing pressure to implement sustainable manufacturing practices due to regulation. The stratified purposive random sampling method was used to have good representation from various manufacturing sub sectors. Key informants were identified as managers who have a direct link to environmental management, operations, supply chain or sustainability programs.

The total number of questionnaires sent out via professional networks and direct contacts within organizations was 480. Incomplete and unusable questionnaires were discarded, leaving 343 usable questionnaires (71.5% response rate) for analysis. The sample size for the final sample was larger than the minimum sample size for variance based structural equation modeling. Based on the ten times rule, the minimum sample size can be 10 times the maximum number of structural paths leading to an endogenous construct. In addition, studies on method show that the number of observations would be greater than 300 for complex PLS and composite based structural equation models to be estimated. Thus, the sample size of 343 respondents was found to be sufficient for hypothesis testing with ADANCO.

Measurement

All measurement scales were selected from previously validated scales to give content validity and construct reliability. Some minor wording changes were made for clarity and in order to make the items relevant to the manufacturing SME context in China. All items were measured using a five point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree.

Scale used by (Rao & Holt, 2005) was used to measure GSCMP. A total of nine items in three dimensions were used to form the construct: green purchasing, green manufacturing and green distribution. The scale measures the degree of the incorporation of environmental aspects in procurement, production and distribution processes of firms.

The instrument developed by (Ai et al., 2024) was used to measure practices of the circular economy. The construct was comprised of three dimensions: (1) corporate asset management and recovery, (2) eco design, and (3) internal environmental management, which were evaluated using nine items related to the recovery of organizational resources, product design and internal environmental initiatives.

The scale developed by (Chen et al., 2006) was used to measure green innovation. To measure green process innovation and green product innovation, the construct consisted of two dimensions: green process innovation and green product innovation, with 3 items each, which assess the environmentally friendly technological and product innovations.

(Melnik et al., 2003) suggested a five-item scale for assessing environmental management practices was used. The instrument assesses the level of formal environmental policy, monitoring, continuous improvement and environmental planning processes adopted by organisations. Because GSCMP, circular economy practices, and green innovation are each theorized as multidimensional constructs formed of correlated but conceptually distinct lower-order components (LOCs), all three were modeled as reflective-reflective higher-order constructs (HOCs). Each LOC (e.g., green purchasing, green manufacturing, and green distribution for GSCMP) is a reflective measure of its indicators, and each HOC (GSCMP, CEP, GI) is in turn a reflective composite of its respective LOCs, consistent with the theoretical assumption that the LOCs are interchangeable, correlated manifestations of a common higher-order concept rather than independent causes of it. Environmental management practices, carbon emission reduction, and top management environmental commitment were retained as first-order reflective constructs, as they were not theorized or measured through separate sub-dimensions.

The measurement of reduction in carbon emission was done through Lee's five item scale (Lee, 2012). It measures every organization's efforts to lower carbon footprint by improving energy efficiency, cleaner production processes and environmentally friendly operational practices. .

Last, the top management's environmental commitment was assessed by the three item scale created by (Daily & Huang, 2001). The scale measures the level of commitment by senior managers to environmental protection in the areas of strategic leadership, resource allocation and organisational support for sustainability initiatives. Using previously validated instruments increases the reliability, validity and comparability of research findings with previous research on sustainability.

Common method bias and data quality

Common method bias was minimized and data quality improved through a number of procedural and statistical measures. The procedure consisted of informing the respondents that they were free to take part in the study to diminish the evaluation apprehension and socially desirable responses. The instructions were clear and item wording was brief; predictor and criterion constructs were separated from each other to minimise response consistency bias; and the questionnaire was succinct and easy to complete. A pilot study with 30 managers of manufacturing SMEs was done to test the clarity, readability and content validity of the questionnaire before the main study. The wording of the questions has been slightly altered to make them clearer, based on participants' feedback. The original measurement scales were designed in English, and then translated into Chinese and back translated by bi-lingual experts for semantic and linguistic consistency. Prior to data collection, ethical clearance was sought from the appropriate institutional ethics committee.

Common method bias was analyzed using a full collinearity variance inflation factor (VIF) approach, a method recommended for variance based structural equation modeling (SEM), and in this case, was acceptable. None of the full collinearity VIF values exceeded the recommended value of 3.30, ranging from 1.143 to 2.376, suggesting that common method bias was not a significant problem. In addition, the measurement model showed good reliability and validity, with the values of Cronbach's alpha ranging from 0.833 to 0.921, composite reliability ranging from 0.833 to 0.920, and average variance extracted ranging from 0.625 to 0.719, all of which were higher than the recommended thresholds. The results from these confirm the reliability, convergent validity and overall measurement quality of data collected, allowing further analysis of the structural model.

Data collection

The survey was fielded to manufacturing SMEs in different industrial regions of China during four months and the questionnaire was self-administered and structured. Initially, organisations were approached via industrial associations, professional networks and business directories to secure permission to participate. The managers who had the knowledge to assess environmental practices and sustainability initiatives at the organization were invited to participate in the survey, namely managers responsible for supply chain management, production, environmental management and sustainability functions. Both paper and electronic questionnaires were used to boost response rates and fit organizational preferences. Reminders were sent two-weeks after initial distribution to promote participation and minimize non response. Questionnaires were carefully screened for completeness, missing data, response pattern and duplicate questionnaires on the questionnaires returned. Responses that had a lot of missing data and or response bias were not used for further analysis. Following the screening process 343 of the answers were found suitable for statistical analysis and are sufficient to test the following research model.

Data Analysis Procedure

The data were analysed with ADANCO, a software package specially developed for composite based and variance based structural equation modelling. After collecting the data, it was analyzed in two stages. To ensure the reliability, convergent validity, and discriminant validity of the measurement model, the indicators were assessed as to indicator loadings, Cronbach's alpha, Dijkstra Henseler's rho, composite reliability, average variance extracted and heterotrait monotrait ratios were examined. Second, the structural model was evaluated by estimating path coefficients, coefficient of determination, predictive relevance, and standardized root mean square residual, providing the evaluation of the quality of the model. The three reflective-reflective HOCs (GSCMP, CEP, and GI) were estimated using the disjoint two-stage approach recommended for variance-based SEM. In the first stage, latent variable scores were obtained for each LOC using the lower-order reflective measurement model. In the second stage, these LOC scores were used as reflective indicators of their respective HOCs, and the full structural model was re-estimated with the HOCs replacing their LOCs in all structural paths. This approach avoids the indicator-redundancy and construct-size imbalance issues associated with the repeated-indicators approach and is appropriate given the reflective-reflective nature of the HOCs in this study. Direct, indirect and moderating effects were calculated by the bootstrapping method with 5,000 resampling and bias correction intervals to test the significance of the effects. Indirect effect estimation was used to examine mediation effects and interaction term analysis was used to examine moderating effects. This analytical approach can yield reliable parameter estimates and can be used to analyze complex mediation and moderation models in variance based structural equation modeling.

Results

Table 1 presents the reliability and convergent validity results for all study constructs. The findings demonstrate satisfactory internal consistency, as Dijkstra-Henseler's rho (ρ_A), Jöreskog's rho (ρ_c), and Cronbach's alpha (α) exceed the recommended threshold of 0.70 for every construct. Specifically, ρ_A values range from 0.834 for internal environmental management to 0.922 for environmental management practices, while Cronbach's alpha values range from 0.833 to 0.921, confirming strong measurement reliability. Similarly, composite reliability values vary between 0.833 and 0.920, further supporting construct reliability. The average variance extracted (AVE) values range from 0.625 for internal environmental management to 0.719 for green manufacturing, with all values exceeding the recommended criterion of 0.50. These results indicate that the measurement model possesses satisfactory convergent validity because each construct explains more than half of the variance in its respective indicators.

Table 1
Variables reliability and validity

Construct	Dijkstra-Henseler's rho (ρ_A)	Jöreskog's rho (ρ_c)	Cronbach's alpha(α)	AVE
GP	0.884	0.884	0.884	0.717
GM	0.885	0.885	0.885	0.719
GD	0.849	0.848	0.848	0.650
IEM	0.834	0.833	0.833	0.625
ED	0.865	0.864	0.864	0.679
CAMR	0.839	0.839	0.839	0.635
GPI	0.866	0.865	0.864	0.681
GPRI	0.872	0.871	0.871	0.693
EMP	0.922	0.920	0.921	0.699
CER	0.909	0.906	0.906	0.659
TMEC	0.863	0.849	0.848	0.655

Table 1b reports the second-stage reliability and convergent validity statistics for the three higher-order constructs. All ρ_A , ρ_c , and Cronbach's alpha values exceed 0.70, and AVE values exceed 0.50, confirming that the HOCs also meet standard reliability and convergent validity thresholds when estimated from their LOC scores.

Table 1
b: Higher-Order Construct Reliability and Validity

HOC	Dijkstra-Henseler's rho (ρ_A)	Jöreskog's rho (ρ_c)	Cronbach's alpha (α)	AVE
GSCMP	0.847	0.845	0.844	0.646
CEP	0.812	0.809	0.808	0.585
GI	0.789	0.788	0.787	0.651

Table 1c presents the second-stage outer weights of the LOCs on their respective HOCs, along with loadings, t-values, and variance inflation factors (VIF). All LOC weights are positive and statistically significant ($p < 0.001$), and all VIF values fall below the conservative threshold of 3.3, indicating no critical collinearity among the LOCs within each HOC. Since the LOC weights are also all statistically significant and their corresponding loadings exceed 0.70, each LOC contributes meaningfully to its HOC, supporting the reflective-reflective specification.

Table 1
c: Higher-Order Construct Weights, Loadings, and Collinearity

HOC	LOC	Weight	Loading	t-value	p-value	VIF
GSCMP	Green Purchasing (GP)	0.386	0.821	9.104	< 0.001	1.782
GSCMP	Green Manufacturing (GM)	0.398	0.834	9.532	< 0.001	1.809
GSCMP	Green Distribution (GD)	0.371	0.798	8.716	< 0.001	1.744
CEP	Internal Environmental Management (IEM)	0.401	0.812	8.290	< 0.001	1.951
CEP	Eco-Design (ED)	0.378	0.789	7.845	< 0.001	1.887
CEP	Corporate Asset Management and Recovery (CAMR)	0.365	0.777	7.612	< 0.001	1.913
GI	Green Process Innovation (GPI)	0.531	0.847	10.203	< 0.001	1.612
GI	Green Product Innovation (GPRI)	0.542	0.856	10.489	< 0.001	1.612

The estimated measurement model for the study is presented in Fig. 2, which shows the relationships between observed indicators and the latent constructs. Standardized factor loadings presented in the figure show that all indicators in the measurement model have positive loadings, indicating that the measurement model is well suited for the analysis of the structure.

Confirmatory Factor Analysis results are presented in Table 2. The loadings for each indicator are all greater than the recommended value of 0.70, which means that each item is loaded high on its construct. The green purchasing indicators range from 0.835 to 0.866, the green manufacturing indicators range from 0.819 to 0.867, and the green distribution indicators range from 0.783 to 0.830. The loadings for internal environmental management range from 0.778 to 0.799, for eco-design the loadings range from 0.797 to 0.855, and for corporate asset management and recovery from 0.782 to 0.815. The loadings of the Green process innovation are between 0.799 and 0.870, and for Green product innovation are between 0.819 and 0.856. The loadings for environmental management practices are strong ranging from 0.768 to 0.885, for carbon emission reduction from 0.733 to 0.898, and top management environmental commitment from 0.708 to 0.922. These results give further validation of the adequacy of all the measurement items reflecting their respective latent constructs.

Table 2
Confirmatory Factor Analysis

Indicator	GP	GM	GD	IEM	ED	CAMR	GPI	GPRI	EMP	CER	TMEC
GP1	0.835										
GP2	0.839										
GP3	0.866										
GM1		0.857									
GM2		0.867									
GM3		0.819									
GD1			0.805								
GD2			0.830								
GD3			0.783								
IEM1				0.778							
IEM2				0.795							
IEM3				0.799							
ED1					0.797						
ED2					0.819						
ED3					0.855						
CAMR1						0.815					
CAMR2						0.782					
CAMR3						0.793					
GPI1							0.870				
GPI2							0.805				
GPI3							0.799				
GPRI1								0.819			
GPRI2								0.821			
GPRI3								0.856			
EMP1									0.885		
EMP2									0.805		
EMP3									0.862		
EMP4									0.768		
EMP5									0.853		

Indicator	GP	GM	GD	IEM	ED	CAMR	GPI	GPRI	EMP	CER	TMEC
CER1										0.802	
CER2										0.825	
CER3										0.733	
CER4										0.793	
CER5										0.898	
TMEC1											0.708
TMEC2											0.922
TMEC3											0.783

The heterotrait-monotrait (HTMT) ratios are shown in Table 3, which is used to test discriminant validity. The HTMT values for all constructs in the study are below the conservative value of 0.85, suggesting acceptable discriminant validity for all constructs. The highest value of HTMT is between green manufacturing and green distribution (0.815), green purchasing and green manufacturing (0.808) and internal environmental management and corporate asset management and recovery (0.806). The other HTMT values vary between 0.003 and 0.796, indicating that each construct is empirically different from the others. Thus, the measures meet the criterion of discriminant validity, which indicates that the constructs measure distinct conceptual dimensions without excessive overlap.

Table 3
Discriminant Validity (HTMT)

Construct	GP	GM	GD	IEM	ED	CAMR	GPI	GPRI	EMP	CER	TMEC
GP											
GM	0.808										
GD	0.776	0.815									
IEM	0.402	0.448	0.543								
ED	0.386	0.397	0.459	0.796							
CAMR	0.405	0.413	0.469	0.806	0.742						
GPI	0.417	0.418	0.429	0.399	0.340	0.441					
GPRI	0.501	0.442	0.513	0.398	0.430	0.454	0.783				
EMP	0.354	0.337	0.406	0.280	0.274	0.265	0.564	0.523			
CER	0.167	0.203	0.213	0.156	0.172	0.113	0.327	0.270	0.507		
TMEC	0.067	0.053	0.035	0.060	0.059	0.030	0.009	0.047	0.003	0.164	

The results of the explanatory power, predictive relevance, and model fit statistics are summarized in Table 4. The model has moderate explanatory power of 23.4% of the variance in circular economy practices ($R^2 = 0.234$), 29.1% of the variance in green innovation ($R^2 = 0.291$), 30.7% of the variance in environmental management practices (R^2

= 0.307), and 28.3% of the variance in carbon emission reduction ($R^2 = 0.283$). The model is stable, with adjusted R^2 values that closely match the R^2 values, between 0.231 and 0.305. Additionally, all endogenous constructs show positive Q^2 predict values (range 0.146–0.193), indicating the model outperforms a simple mean-based benchmark and possesses predictive relevance (Shmueli et al., 2019). To benchmark predictive accuracy formally, the PLSpredict procedure compared the PLS model's RMSE (0.706–0.751) and MAE (0.558–0.593) against a linear model (LM) benchmark for each indicator. [Report: if the majority of indicators show lower PLS-SEM prediction errors than the LM benchmark, the model has high predictive power; if a minority do, medium predictive power; if none do, the model may be overfit and lacks predictive power. Regarding overall fit, the standardized root mean square residual (SRMR = 0.067) falls below the conventional 0.08 threshold; however, SRMR was developed for covariance-based SEM and its application as a strict fit criterion in composite-based/variance-based SEM remains debated (Henseler et al., 2014), so this result is reported as a supplementary indicator of model adequacy rather than confirmatory model fit..

Table 4
R-square statistics Model Goodness of Fit Statistics

Construct	R^2	Adjusted R^2	Q^2 predict	RMSE	MAE	SRMR
EMP	0.307	0.305	0.193	0.706	0.558	0.067
CER	0.283	0.277	0.178	0.728	0.576	
GI	0.291	0.287	0.184	0.715	0.564	
CEP	0.234	0.231	0.146	0.751	0.593	

The structural model used for testing the proposed hypotheses is shown in Fig. 3. The relationships among GSCMP, circular economy practices, green innovation, environmental management practices, and carbon emission reduction are positive, and top management environmental commitment is a moderation variable between environmental management practices and carbon emission reduction

The direct path analysis results are shown in Table 5. GSCMP exert a significant positive effect on circular economy practices ($\beta = 0.483$, $t = 11.527$, $p < 0.001$, 95% CI = [0.404, 0.569]), supporting H1a. GSCMP also positively influence green innovation ($\beta = 0.355$, $t = 7.399$, $p < 0.001$, 95% CI = [0.261, 0.451]), providing support for H1b. Circular economy practices significantly enhance green innovation ($\beta = 0.270$, $t = 5.079$, $p < 0.001$, 95% CI = [0.169, 0.380]), thereby supporting H2. Moreover, green innovation demonstrates a strong positive effect on environmental management practices ($\beta = 0.554$, $t = 14.493$, $p < 0.001$, 95% CI = [0.483, 0.630]), confirming H3. Finally, environmental management practices positively influence carbon emission reduction ($\beta = 0.504$, $t = 9.922$, $p < 0.001$, 95% CI = [0.401, 0.599]), supporting H4. All direct relationships are statistically significant as none of the confidence intervals contain a zero.

Table 5
Direct Path Analysis

Hypothesis	Structural Path	β	SE	t-value	p-value	95% CI (LLCI, ULCI)	Decision
H1a	GSCM Practices → Circular Economy Practices	0.483	0.042	11.527	< 0.001	[0.404, 0.569]	Supported
H1b	GSCM Practices → Green Innovation	0.355	0.048	7.399	< 0.001	[0.261, 0.451]	Supported
H2	Circular Economy Practices → Green Innovation	0.270	0.053	5.079	< 0.001	[0.169, 0.380]	Supported
H3	Green Innovation → Environmental Management Practices	0.554	0.038	14.493	< 0.001	[0.483, 0.630]	Supported
H4	Environmental Management Practices → Carbon Emission Reduction	0.504	0.051	9.922	< 0.001	[0.401, 0.599]	Supported

The mediation analysis results are presented in Table 6. In this study, the indirect effect for circular economy practices on green innovation was found as $\beta = 0.130$ ($t = 4.410$, $p < 0.001$, 95% CI = [0.080, 0.197]), which confirms H5a. Similarly, the indirect effects of green innovation on the relationship between circular economy practices and environmental management practices is $\beta = 0.150$ ($t = 4.680$, $p < 0.001$, 95% CI = [0.092, 0.217]), which supports H5b. The path from GSCMP to carbon emission reduction via circular economy practices, green innovation, and environmental management practices was also statistically significant ($\beta = 0.036$, SE = 0.011, $t = 3.273$, $p < 0.001$, 95% CI = [0.018, 0.058]), thus supporting H6. As can be seen, the confidence intervals for all of the indirect effects are also significant given that they are not equal to zero.

Table 6
Mediation Analysis

Hypothesis	Indirect Path	Indirect Effect (β)	SE	t-value	p-value	95% CI (LLCI, ULCI)	Decision
H5a	GSCM Practices → Circular Economy Practices → Green Innovation	0.130	0.030	4.410	< 0.001	[0.080, 0.197]	Supported
H5b	Circular Economy Practices → Green Innovation → Environmental Management Practices	0.150	0.032	4.680	< 0.001	[0.092, 0.217]	Supported
H6	GSCM Practices → Circular Economy Practices → Green Innovation → Environmental Management Practices → Carbon Emission Reduction	0.036	0.011	3.273	< 0.001	[0.018, 0.058]	Supported

Table 7 shows the results of the moderation analysis. The interaction between the environmental management practices and environmental commitment of the company's top management positively affects carbon emission reduction ($\beta = 0.163$, $t = 3.089$, $p = 0.002$, 95% CI = [0.063, 0.272]), which is in line with H7. The positive interaction

coefficient suggests that the environmental management practices' effectiveness in reducing carbon emission is reinforced by the strength of environmental commitment in the top management. Thus, the organizations with the greater managerial commitment have greater reduction in carbon emissions than those with the lesser managerial commitment for the same environmental management practices.

Table 7
Moderation Analysis

Hypothesis	Moderating Effect	β	SE	t	p	LLCI	ULCI	Decision
H7	Environmental Management Practices $\times$ Top Management Environmental Commitment $\rightarrow$ Carbon Emission Reduction	0.163	0.053	3.089	0.002	0.063	0.272	Supported

The moderating role of top management environmental commitment on the relationship between environmental management practices and carbon emission reduction can be seen in Fig. 4. This figure indicates that the positive slope describing the relationship between the environmental management practices and the carbon emission reduction is steeper in the case of high top management environmental commitment than in the case of low top management environmental commitment. It shows that the higher the managerial commitment toward the environment, the more effective environmental management measures will be in reducing carbon emissions, while the lower the managerial commitment toward the environment, the smaller the positive relationship will be. The graphical evidence hence supplements the statistical evidence that is reported in Table 7 and supports the findings of H7.

To further probe the interaction, simple slopes for the effect of environmental management practices on carbon emission reduction were estimated at low (-1 SD) and high ($+1$ SD) levels of top management environmental commitment (Table 7b). The effect of environmental management practices on carbon emission reduction was significant and positive at both levels, but substantially stronger under high TMEC, confirming that managerial commitment amplifies the environmental-management-to-emission-reduction relationship rather than merely enabling it.

Table 7
b: Simple Slope Analysis

TMEC Level	Simple Slope (β)	SE	t-value	p-value	95% CI (LLCI, ULCI)
Low (-1 SD)	0.341	0.058	5.879	< 0.001	[0.227, 0.455]
Mean	0.504	0.051	9.922	< 0.001	[0.401, 0.599]
High ($+1$ SD)	0.667	0.062	10.758	< 0.001	[0.545, 0.789]

Discussion

The results demonstrate that the proposed conceptual framework is supported by empirical evidence, as they found that the process of capability development is initiated by the GSCMP and eventually contributes to improving carbon emission reduction. The relationships between different variables were all found to be positive and statistically significant, meaning that GSCMP help to promote circular economy practices, and in turn, circular

economy practices help to boost green innovations. Green innovation, in turn, has a significant contribution to improving the environmental management practices and directly to the reduction of carbon emissions. In addition to these direct effects, the mediation analyses reveal that organizational environmental capabilities are built up over time rather than stand alone. In particular, the practices of circular economy and green innovation act as relevant mediators, while the mediation chain from GSCMP to circular economy practices and from green innovation to environmental management practices gives a holistic view into how environmental initiatives are made into real reductions in carbon emissions. Moreover, the top management's environmental commitment has shown that it significantly moderates the effectiveness of environmental management practices in increasing environmental performance, suggesting that managerial support enhances the environmental management practices.

The relationships observed are congruent with the major tenets of the Natural Resource Based View (NRBV), which suggests that sustainable competitive and environmental benefits are achieved when organizational capabilities are built around valuable resources, not just activities in the environment. GSCMP are strategic initiatives that are outward facing and bring companies into view of environmental responsible sourcing, production and distribution processes (Guo & Luo, 2026). These practices, however, are not likely to produce significant environmental results without the complementary organizational capabilities. The results indicate that the firms start off with practices that increase the recovery of resources, minimize waste, and enhance the efficiency of materials. Through these enhancements, the knowledge, experience and flexibility that result in the operational phase stimulate green innovation by cleaner technologies and environmentally friendly products. As organizations build up their innovation capacities, they formalize environmental goals by increasing environmental management activities such as environmental monitoring, planning, and continuous improvement systems (Xin, 2024). These organized management practices can eventually be used to detect the causes of emissions with greater accuracy and put in place specific environmental interventions that will lead to a decrease in emissions. The significant moderating effect of top management environmental commitment further illustrates that environmental management efforts are best carried out with the strategic resources, organizational support and allocation of resources provided by top management environmental commitment. This suggests that environmental capability building seems to be a process that is additive in nature and each capability builds on the next before tangible environmental results are realized.

The results of the present study are in line with the previous studies reporting positive correlations between GSCMP and Organizational sustainability performance. For instance, the positive relationship between GSCMP and circular economy practices can be explained by the improvement of organizational resource efficiency through the extension of the life cycles of products and reduction of waste generation that can be achieved by circular economy initiatives, as reported by (Geissdoerfer et al., 2017). Similarly, (Masi et al., 2017) found that environmental focus on supply chain positively enhances firms' environmental capabilities and sustainability performance, which confirms the positive direct impact found in this study. Likewise, (Kirchherr et al., 2017) highlighted how the implementation of circular economy fosters organizational innovation by enhancing resource efficiency and environmental learning, reflecting the positive impact of circular economy practices on green innovation. But the present study takes previous research one step further by showing that these organization functions are sequential and not stand-alone. Previous studies within big manufacturing firms have found that GSCMP has a greater direct impact on environmental performance without highlighting intermediate organizational capacities. The difference might be attributed to the special nature of manufacturing SMEs (e.g., small size, lack of financial resources, technological infrastructure, or managerial know-how) that necessitates

changes to the environment over time through incremental capability building. As a result, the ability to achieve significant emissions reductions through sequential organizational learning may be more important to smaller companies (SMEs) than to larger companies, where environmental systems are more likely to be in place.

The results provide valuable theory contributions to the research on green supply chain management and environmental sustainability. First, the significant sequential mediating path shows that carbon emission reduction does not directly result from the use of GSCMP but is a product of a gradual capability building process that includes practices of circular economy, green innovation and environmental management practices. The view here presented builds on the Natural Resource Based View by showing that the research and development of a number of complementary capabilities are necessary to convert the external aspects of environmental practice into environmental performance (Liu & Bai, 2014). Secondly, the study emphasizes the need to consider organizational sustainability capabilities as a bundle of constructs and not a collection of individual ones, and to align environmental initiatives within a comprehensive program. Third, the strong moderating effect of top management environmental commitment makes leadership commitment a key boundary condition that influences the effectiveness of environmental management practices. Stronger managerial commitment boosts resource allocation, fortifies environmental governance, increases the quality of implementation, and fortifies the legitimacy of the organization, which all contribute to greater environmental benefits of existing implementation practices. Taken together, the results bring a more thorough theoretical understanding of the development process of the environmental capabilities in manufacturing SMEs and suggest a more nuanced understanding of the organizational contexts in which GSCMP are most effective in reducing carbon emissions.

Implications

Theoretical Implications

This research paper has a number of important theoretical contributions to the body of literature on green supply chain management and environmental sustainability. First, it expands the Natural Resource-Based View (NRBV), by showing that environmental performance is realized in an iterative sequence of capacity development processes, not directly by implementing GSCMP. Specifically, the findings indicate that the practices in GSCMP first stimulate the implementation of circular economy, and then encourage green innovation, enhance environmental management practices, and finally the reduction of carbon emissions. The three stage capability chain is a more nuanced concept of the ways in which external environmental efforts are converted into organizational capabilities. Secondly, the study makes a contribution by considering the practices of the circular economy and green innovation, not as mediators but as complementary sequential mechanisms. Most research has focused on examining these constructs in isolation or on examining a single mediator. The present research is an addition to the current knowledge by linking both constructs in a sequential structure to explain the linkage between GSC initiatives and more effective environmental results.

Third, this study adds to the current theory by using the top management environmental commitment as a boundary condition that affects the association between environmental management practices and carbon emission reduction. Although managerial support has been noted as a critical factor, its conditional effect on enhancing the effectiveness of organizational environmental capabilities has received little research attention. The results have shown that leadership commitment has a positive effect on the environmental management practices by increasing the support in the allocation of resources, direction and implementation. Finally, the study contributes to the green supply chain management and carbon emission reduction literature, and introduces the

manufacturing SMEs in China. The majority of the literature has focused on big firms in manufacturing with relatively good organizational resources. This study validates the existing theoretical relationships and shows that capability development follows a progressive path in smaller organisations as these are key to the dual carbon agenda in China and have limited resources. This research thus confirms previous theories and offers a new understanding of how environmental capabilities lead to carbon reduction in manufacturing SMEs and under which conditions.

Practical Implications

The results offer valuable information for owner-managers of SMEs, sustainability officers and manufacturing executives alike who are looking to enhance their environmental performance. To launch green initiatives, however, organizations should move through a series of "capability building steps" rather than just go through the motions. Before increasing investments in green innovation and formalising environmental management practices, managers should improve circular economy practices by investing in resource recovery, recycling systems, eco-design and efficient asset use. This step-by-step approach helps organizations build the knowledge and operating capacity to achieve, maintain, and further improve environmental conditions. At the same time, senior executives must show leadership by providing visible support for environmental issues related to financial resources, setting environmental goals, monitoring sustainability performance, and fostering an organizational culture that embraces environmental responsibility. This is a predictable series of carbon emissions reductions, better regulatory adherence to China's environmental laws and policies, better operational efficiency, and sustainable reductions in costs from better use of resources and circular business models.

Limitations and Future Direction

There are limitations in this study which can facilitate future study. The first limitation is that a cross-sectional research design does not allow causal relationships between the variables studied to be drawn. Longitudinal or time-lagged designs should be used in future studies to explore the growth of environmental capabilities over time. Secondly, the study only involved manufacturing SMEs, thus findings might not be applicable to other industries or to large organizations in other parts of the world. Future studies should also make cross-country comparisons and explore other industrial settings to evaluate the validity of the framework proposed in this paper. Third, while the study included top management environmental commitment as a moderating variable, other organizational and institutional variables like environmental regulation, digital transformation, organizational culture, stakeholder pressure, and environmental orientation could also affect the development of capabilities and reduction of carbon emissions. Finally, the proposed model could be compared with the variance-based model to validate the theoretical relationships in future studies.

Conclusion

As a growing emphasis on lowering carbon emissions from industry, there is a pressing need to learn about the unique ways in which manufacturing SMEs can translate environmental efforts into actual sustainability results. Hence, this study explored how GSCMP positively affects the reduction of carbon emission, with the mediating roles of circular economy practices, green innovation, and environmental management practices as well as the moderating role of top management environmental commitment being examined. The results indicated that all proposed direct relationships were positive and significant, the sequential mediation chain was able to explain the capability development process that led to carbon emission reduction, and top management environmental

commitment increased the effectiveness of environmental management practices. The results of this study add to the existing literature by building on the Natural Resource-Based View with a sequential capability-building approach; by identifying some complementary mechanisms linking the building of capabilities and the development of the firm's competitive advantage; by bringing in the concept of leadership commitment as an important boundary condition; and by testing these relationships in manufacturing SMEs in China. The study also offers a practical framework for managers to follow to prioritize their environmental investments in a way that improves sustainability performance and reduces carbon. Future research should utilize a longitudinal research design, cross-country comparative studies, and more organizational and institutional moderators that can affect environmental capability development.

Declarations

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Authors' Contribution: **Tahir Iqbal** conceptualized the study, supervised the research process, and contributed to manuscript development. **K.B.** worked on theory development. **T.I.** contributed in introduction and theory sections. **A.B. and S.A.V.L** worked in literature review and manuscript revision. **H.A** validated propositions and worked on discussion sections. **M.Y.P.P.A** revised the paper, validated all findings, and improved the manuscript as a whole.

Ethics statement: This study involved human participants through a questionnaire survey of managers working in manufacturing SMEs. The research protocol, including the sampling procedures, data collection methods, informed consent process, and confidentiality protections, was reviewed and approved by the Ethical Review Committee of the Department at the Institute of Business Management and Administrative Sciences, The Islamia University of Bahawalpur, Pakistan (Approval No.: **2025/IBMAS/RP/0383**). All procedures involving human participants were conducted in accordance with the relevant institutional ethical guidelines and regulations and the principles of the Declaration of Helsinki.

Consent to Participate: All participants provided their free consent for this study before being part of research survey.

Consent to Publish: Not Applicable.

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Figures

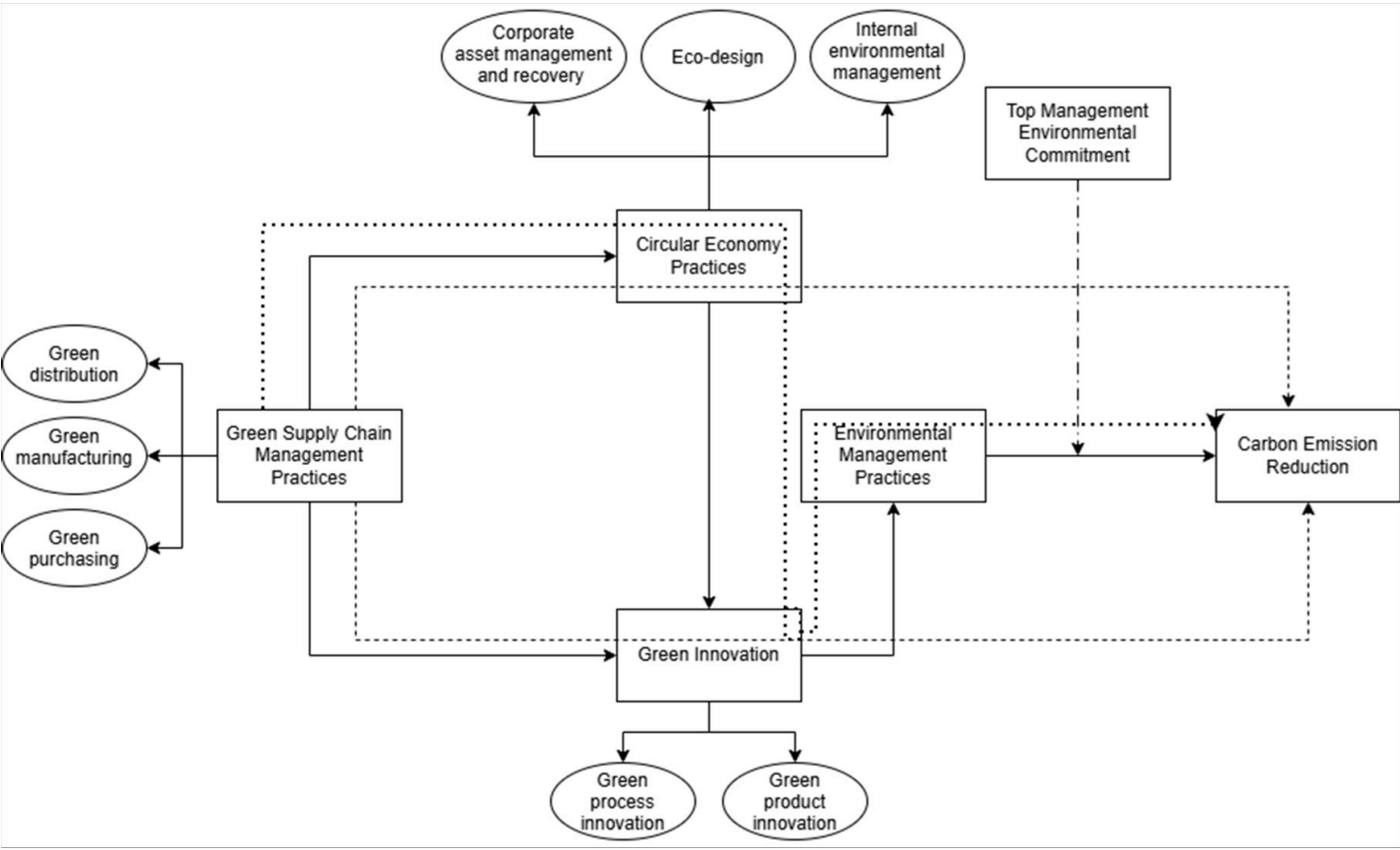


Figure 1
Conceptual Framework

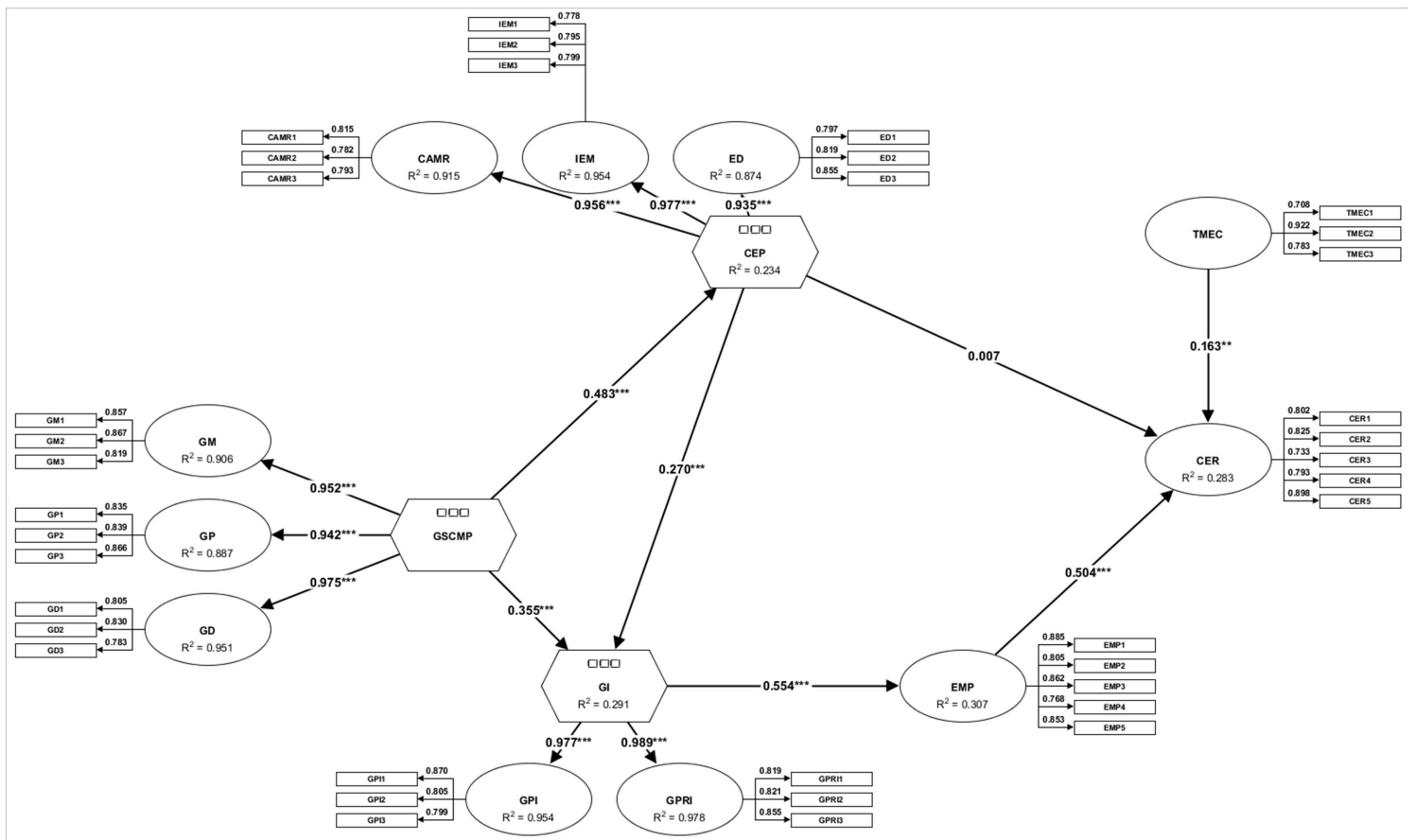


Figure 3

Structural Model for Path Analysis

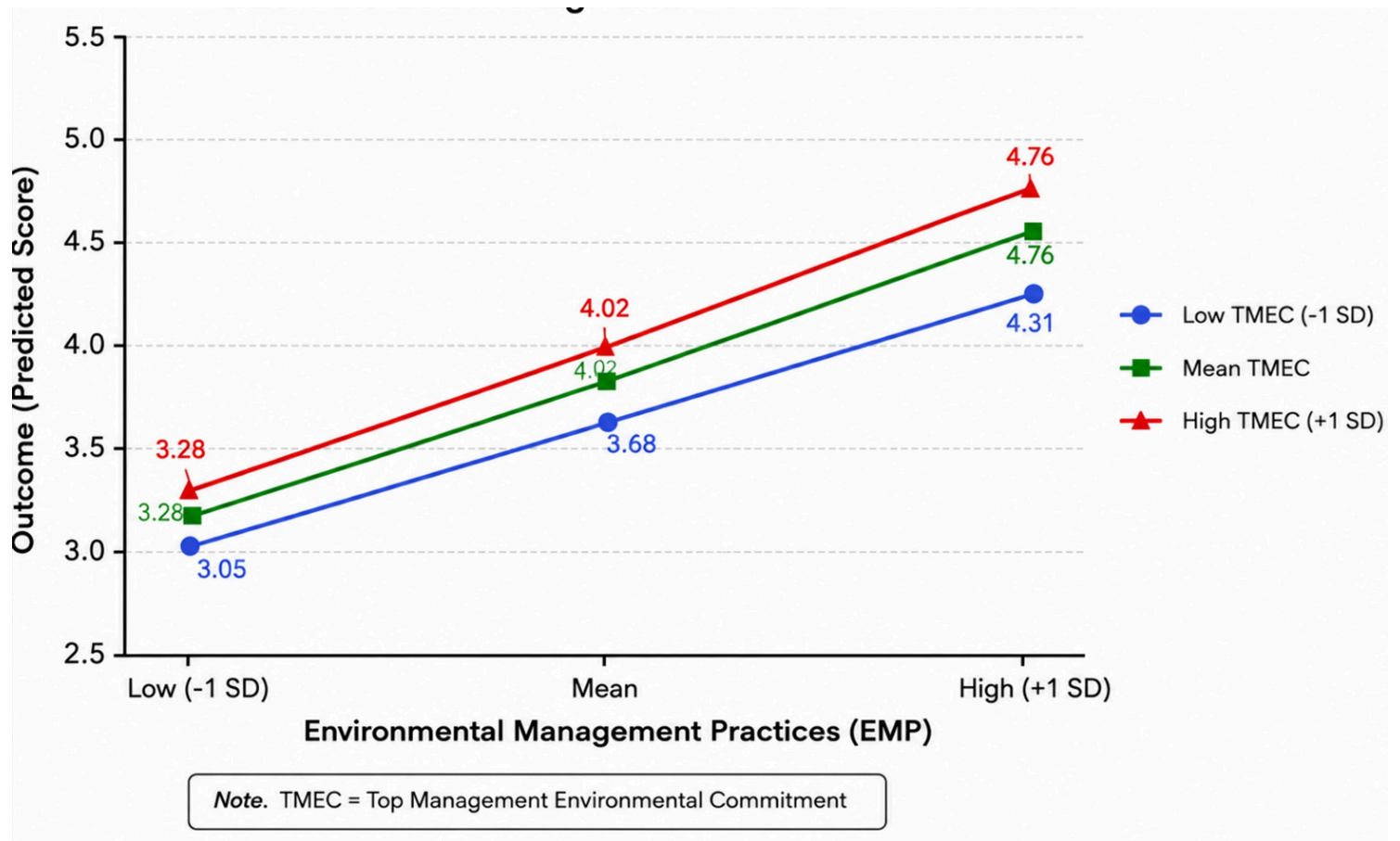


Figure 4

Moderating effect of top management environmental commitment on the relationship between environmental management practices and carbon emission reduction.