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Linking green supply chain management and blockchain technology to green marketing and environmental performance: the mediating role of green technology innovation

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Abstract

Purpose – Drawing on the dynamic capabilities view and the practice-based view, this study develops a conceptual model to empirically test the interrelationships between green supply chain management (GSCM), blockchain technology (BCT), and their impact on green marketing and environmental performance. Special attention is given to the mediating role of green technology innovation (GTI) in these relationships.

Design/methodology/approach – Data were collected from 281 respondents, comprising managers and executives from diverse functional areas, across 93 firms in Türkiye, a key emerging market. The mediating effects of GTI were tested using Hayes' PROCESS macro (Model 4), providing robust insights into the dynamics of GSCM and BCT in driving sustainability.

Findings – The results confirm that BCT positively influences GSCM, reinforcing the role of digital technologies in enhancing sustainability. The study further reveals that GTI significantly mediates the relationship between GSCM and environmental performance, suggesting that firms can enhance their environmental outcomes by adopting innovative, eco-friendly technologies. Additionally, the mediating role of GTI is evident in the relationship between BCT and both environmental and green marketing performance, highlighting the importance of technological integration in sustainability efforts.

Research limitations/implications – While the study provides valuable insights, its focus on firms in Türkiye may limit the generalizability of the findings to other regions. Future research could explore these relationships in other emerging economies and examine additional mediating or moderating variables, such as organizational culture or regulatory pressures, to provide a more detailed understanding of the dynamics between BCT, GSCM, and firm performance.

Practical implications – The findings provide actionable insights for managers, particularly in emerging markets. By adopting BCT, firms can improve supply chain transparency and efficiency, while enhancing both environmental sustainability and marketing performance. Integrating GTI into GSCM practices helps firms meet regulatory demands and gain a competitive advantage in eco-conscious markets.

Originality/value – This paper contributes to the limited literature on the intersection of BCT, GSCM, and firm performance, particularly within the underexplored context of Türkiye. It provides a unique perspective on how

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emerging technologies and green innovations can be harnessed to achieve both environmental and marketing outcomes.

Keywords Green supply chain management, Blockchain technology, Green marketing performance, Environmental performance, Green technology innovation, Türkiye

Paper type Research article

1. Introduction

To reach more challenging sustainability goals, organizations need to take an active role and focus on the external environment, often referred to as the "going green" initiative (Bansal and Roth, 2000). The "green" concept involves the integration of environmental or ecological considerations into operations. As a key aspect of operations management, the supply chain (SC) has a significant impact on the environment, contributing to emissions, pollution and health risks to communities (Flint, 2004). Organizations are increasingly working to reduce their environmental footprint by integrating environmental considerations into their SC processes (Tseng *et al.*, 2019). Green SCs represent a contemporary management approach in supply chain management (SCM) integration, focusing on efficiency, environmental sustainability, and maintaining close relationships with manufacturers, suppliers, retailers, and consumers (Chen *et al.*, 2012). Green supply chain management (GSCM) is attracting growing attention from both researchers and practitioners in the fields of operations and SCM (Balon, 2020; Davies *et al.*, 2023). This heightened focus on GSCM is primarily due to the worsening environmental conditions, such as the depletion of raw material resources, the overflowing of waste sites, and the rising levels of pollution (Srivastava, 2007).

In this study, blockchain is treated as an antecedent due to its widely recognized potential to enhance transparency across organizational systems. This is particularly relevant in the context of GSCM, where transparency and traceability of environmentally friendly practices are crucial. This peer-to-peer (P2P) network-based technology is gaining popularity for its ability to streamline business processes by verifying and sharing data efficiently (Cole *et al.*, 2019). Blockchain technology (BCT) has become a potentially essential tool for companies to address the growing complexity and risks within global SCs (Gligor *et al.*, 2022). BCT represents a new model for computing and information flow, with significant implications for the future evolution of SCM and logistics (Abeyratne and Monfared, 2016).

BCT can emphasize and provide detailed information on at least five critical product dimensions: its nature (what it is), quality (how it is), quantity (how much there is), location (where it is), and ownership (who owns it at any given time) (Silvestri *et al.*, 2024). By doing so, BCT eliminates the need for a trusted central authority to manage and operate the system, allowing customers to track the continuous chain of custody and transactions from raw materials to the final sale. These details are documented in ledgers as transactions occur across these various BCT dimensions, with verifiable real-time updates (Martino, 2021).

Previous studies have demonstrated that environmental performance is influenced by factors such as the types of primary and auxiliary materials utilized, energy components, product development technologies, and the environmental impact arising from a firm's operational and administrative activities (Aftab *et al.*, 2023). Many environmental issues do not stem from a manufacturer's internal operations but are linked to its upstream and downstream SCs. To implement proactive environmental strategies and programs, collaboration across the SC is essential. Additionally, the environmental awareness and capabilities of SC partners play a crucial role in ensuring effective environmental protection (Yu *et al.*, 2019). The increasing focus on environmental protection has now evolved into the implementation of green policies. When SCM practices are valuable, rare and difficult to imitate, they can lead to sustainable competitive capabilities. In other words, the SC acts as a source of competitive advantage that drives the success of the firm (Kim, 2009).

GSCM is viewed also as a key component of organizational strategy for companies aiming to become environmentally conscious and socially responsible, meet customer expectations, and comply with government regulations (Bu *et al.*, 2020). While previous research has addressed the impact of marketing performance on SC outcomes (Salam and Bajaba, 2023), the bidirectional nature of this relationship, particularly in the context of sustainability, remains underexplored. The existing literature has long recognized the interdependence between the SC and marketing functions. For example, Min and Mentzer (2000) demonstrated that the integration of these functions enhances coordination and strengthens customer value creation. Similarly, Jüttner *et al.* (2007) argue that the integration of SC and marketing functions can create value beyond the traditional scope of marketing. Ellinger (2000) further emphasizes that such cross-functional alignment creates synergies that have long been considered essential for achieving competitive advantage.

Although sustainability goals are shared globally, the ways in which they are implemented and communicated can differ significantly across countries (Dangelico and Vocalelli, 2017). Technologies like BCT may enhance transparency, but how this transparency is perceived and valued varies depending on local regulations, cultural expectations, and consumer sensitivities (Casino *et al.*, 2019). As a result, sustainable SCM practices need to be considered both from an operational perspective and through the lens of international marketing strategy (Papadas *et al.*, 2019). As firms expand their sustainability efforts beyond national borders, BCT-supported GSCM practices evolve from being purely operational mechanisms into strategic tools for building legitimacy in diverse markets (Sunil Kumar, 2025). Effectively aligning these practices with localized marketing narratives enables companies to convey environmental value in ways that resonate across cultural and regulatory contexts (Siaw, 2025).

Building on this foundation, the present study contributes to literature by reversing the conventional direction of analysis: rather than focusing on how marketing influences SC outcomes, it examines the extent to which GSCM influences green marketing performance. In doing so, our study offers a broader and more sustainability-focused perspective on the SC-marketing interface. Strategies that enhance the competitive position of the SC not only improve SC performance but also, over time, positively impact the organizational performance of each SC partner. Additionally, these strategies contribute to better marketing performance by increasing the organization’s ability to generate sales compared to the industry average (Green *et al.*, 2012).

Green innovation is fundamentally a holistic and integrated approach to sustainable development, aiming to harmonize environmental conservation with technological advancement in energy efficiency (Luo *et al.*, 2023). Green technology innovation (GTI) is expected to serve as a crucial force in shaping future economic development (Ahmad and Wu, 2022; Javed *et al.*, 2024). In terms of environmental and marketing performance, its importance lies in driving the adoption of sustainable practices that simultaneously reduce ecological impacts and enhance competitive advantage. By leveraging green technologies, companies can innovate in areas such as energy efficiency, pollution control, and resource recycling, thereby meeting the growing consumer demand for environmentally friendly products (Dam *et al.*, 2024; Saqib *et al.*, 2024). This not only strengthens brand reputation and fosters customer loyalty but also contributes to long-term profitability and the reduction of environmental footprints (Song *et al.*, 2019).

In this study, GTI serves as a key mediator in the relationship between BCT and both environmental and green marketing performance. As a disruptive innovation, BCT has the capacity to transform various aspects of a company’s operations, including its environmental sustainability (Tawiah *et al.*, 2022). BCT-driven GTI enhances environmental performance through ecological protection and improved resource efficiency, while also impacting marketing performance by promoting sustainable practices that align with consumer preferences and emerging market trends (Li, 2021). This dual effect positions BCT as a foundational enabler of sustainability-driven excellence, facilitating operational advances such as improved resource utilization and environmental compliance, while enhancing marketing effectiveness through the development of green value propositions that resonate with environmentally conscious consumers and evolving regulatory expectations (Casino *et al.*, 2019; Queiroz and Wamba, 2019; Tiwari *et al.*, 2018).

In addition, GTI is proposed to mediate the relationship between GSCM and both environmental and green marketing performance. The adoption of GSCM practices fosters continuous innovation and facilitates the discovery of new market opportunities. Firms that integrate sustainable practices not only meet the growing demand for environmentally responsible products but also comply with evolving regulations, thereby strengthening their competitive positioning (Chang *et al.*, 2010). By embedding GTI into GSCM, firms can further amplify the positive effects on both environmental outcomes and marketing performance, ensuring long-term sustainability and market leadership.

This study makes several significant contributions to the existing literature on GSCM. First, the study emphasizes a practical perspective by highlighting the critical role that BCT plays in GSCM. BCT's ability to enhance transparency, traceability, and data security directly supports the effective implementation of sustainable SCM practices. In line with the dynamic capabilities view (DCV) and practice-based view (PBV), this integration not only leads to improved environmental outcomes but also positively influences green marketing by ensuring that environmentally responsible practices are embedded throughout the SC. This contribution is particularly relevant as firms increasingly seek to leverage technology for both operational and reputational gains in a sustainability-conscious market.

Secondly, we propose that the relationship between BCT, GSCM and performance is indirect, with GTI acting as a key mediating capability. While BCT enhances transparency and traceability in SCs (Queiroz and Wamba, 2019), it is GTI that enables firms to translate digital capabilities into environmental and marketing advantages. As emphasized by Wamba *et al.* (2020), digital tools must be embedded in innovation strategies to realize performance outcomes. Our model positions GTI as a dynamic capability (DC) that links technological infrastructure and sustainability practices to competitive impact (Dubey *et al.*, 2020).

Thirdly, this study enhances and expands our understanding of GSCM within the context of an emerging market economy, Türkiye. As a rapidly industrializing country with growing environmental challenges, Türkiye presents a unique context for examining the adoption of BCT and green technologies (Hacioglu *et al.*, 2021). The country's strategic location between Europe, Asia, and the Middle East makes it a critical player in global SCs, where the integration of sustainable practices is increasingly essential (Arda *et al.*, 2023). By focusing on Türkiye, this study offers valuable insights into how firms in emerging markets manage regulatory pressures and sustainability demands while leveraging advanced technologies to enhance both environmental and marketing performance (Bouguerra *et al.*, 2024). These dynamics are not unique to Türkiye; similar institutional and operational challenges are observed across other emerging economies, where firms must simultaneously respond to external pressures and build internal capabilities. As demonstrated in prior research from China, India, and Brazil, the integration of GSCM with digital technologies like BCT and green innovation practices enables firms to improve adaptability and performance under constrained conditions (de Sousa Jabbour *et al.*, 2018; Kamble *et al.*, 2020). By aligning with these global cases, our study shows how sustainability-oriented technological integration supports competitive advantage in emerging markets, while linking the findings to international marketing by recognizing cross-border cultural, regulatory, and consumer variations that shape GSCM and BCT adoption (Craig and Douglas, 2006; Cavusgil and Knight, 2015).

The remainder of this paper is structured as follows. In the next section, the theoretical background is reviewed, and the research hypotheses along with the conceptual model are developed. The third section describes in detail the research methodology, including sampling, measures, and data analysis procedures. Then, the empirical findings are presented and discussed. Finally, the paper concludes with theoretical and managerial implications, limitations of the study, and directions for future research.

2. Literature review and hypothesis development

This section integrates insights from both the DCV and PBV to explore how firms strategically align GSCM practices with BCT and GTI. This approach provides a comprehensive framework for understanding how environmental sustainability and operational practices interact to influence environmental and green marketing performance. The ensuing subsections present the theoretical background, define key concepts, and outline hypotheses to explain the mechanisms underlying these relationships.

2.1 Theoretical background

This study employs both the DCV and the PBV to construct a robust theoretical framework. These two perspectives complement each other by explaining how firms manage their resources, adapt to changes, and create competitive advantages in the context of environmental sustainability and SCM. In response to growing calls to link sustainability with international marketing challenges, this framework also provides a basis to explore how green capabilities and practices may be transferred or adapted across borders (Chabowski *et al.*, 2025).

DCs refer to a firm's ability to renew, integrate, and reconfigure internal and external resources to adapt to rapidly changing environments (Teece *et al.*, 1997). DCs are essential for long-term success in dynamic industries, as they enable firms to continuously develop new capabilities in response to evolving market conditions and technological advancements (Wong, 2013). The three key processes of DCs (i.e., integration, learning, and reconfiguration) are crucial in determining how effectively a firm can adapt to new opportunities or challenges. Integration involves coordinating activities and resources within the firm and with external partners, including suppliers and customers. Learning focuses on acquiring new resources and capabilities, while reconfiguration refers to transforming and recombining existing resources to meet the demands of changing conditions (Hamid Hawass, 2010; Pavlou and El Sawy, 2011). In cross-border settings, these dynamic processes are especially important as firms must adapt to varying regulatory, cultural, and market contexts while maintaining sustainability standards (Ebabu *et al.*, 2025).

When applied to the context of environmental sustainability, the DCV emphasizes a firm's capacity to integrate environmental initiatives into its operations, develop new environmental capabilities, and reconfigure its resource base in response to sustainability pressures (Vanpoucke *et al.*, 2014). For instance, the adoption of GSCM practices requires firms to dynamically reconfigure their SCs to meet environmental goals, such as reducing emissions or minimizing waste. Moreover, as firms gain recognition as "green," this label can become a valuable asset, enhancing their marketing and SCM activities (Chan *et al.*, 2012). When these environmentally sustainable resources align with the firm's broader strategy, they can become rare and difficult to imitate, thus contributing to the firm's overall competitive advantage (Richey *et al.*, 2014). Such environmental reputations may also serve as signaling mechanisms in international markets, strengthening brand positioning and consumer trust in diverse cultural settings (Jain *et al.*, 2024).

On the other hand, the PBV complements the DCV by emphasizing the importance of specific, firm-level practices in creating competitive advantages. While the DCV focuses on the firm's dynamic ability to adapt and change, the PBV focuses on the tangible practices that firms adopt to implement strategies and achieve performance improvements. PBV highlights how certain practices, such as those involved in GSCM, can be key to driving both operational efficiency and environmental sustainability (Bromiley and Rau, 2014). In this framework, green practices, such as the use of environmentally-friendly technologies, sustainable procurement, and resource-efficient production processes, are viewed as critical to achieving sustainable competitive advantage (Bıçakcıoğlu *et al.*, 2020).

In the context of GSCM, the PBV highlights the importance of firm-specific actions that link environmental sustainability to business performance (Stadtfeld *et al.*, 2024). For example, practices like green procurement or reverse logistics are not just operational choices but strategic actions that can enhance both environmental and marketing performance. By focusing on the practical implementation of GSCM, the PBV highlights how firms can leverage these practices to create value, linking sustainability efforts with tangible outcomes such as improved customer loyalty, enhanced brand reputation, and increased market competitiveness (Alghababsheh, 2024).

While the DCV explains how firms develop and refine their capabilities to respond to environmental challenges, the PBV offers insight into how specific practices can be implemented to achieve those outcomes (Belhadi *et al.*, 2022). This study integrates the DCV and PBV to examine how GTI influences the relationships among BCT, GSCM, environmental performance, and green marketing performance. The resulting theoretical foundation enables an exploration of both the dynamic nature of capabilities and the operational significance of green practices in shaping firm performance.

Operating across international markets requires firms to develop DCs, including adaptation, reconfiguration, and sensing, to effectively address the challenges posed by diverse environmental regulations, cultural expectations, and institutional frameworks. Similarly, practice-based routines related to sustainability and innovation must be continuously adapted to maintain strategic relevance across institutional settings (Fernandes *et al.*, 2025).

2.1.1 Green supply chain management. The concept of GSCM revolves around the integration of environmental management principles into every phase of the SC. As Handfield *et al.* (1997) emphasize, GSCM involves incorporating environmental considerations into all activities throughout the entire customer order cycle. Srivastava (2007) provides a widely accepted definition of GSCM, describing it as the integration of environmental thinking into SCM. This includes key stages such as product design, material sourcing and selection, manufacturing processes, the delivery of the final product to consumers, and end-of-life management of products after their useful lifespan.

The origins of GSCM can be traced back to significant industrial revolutions, including the quality revolution of the 1980s and the SC revolution of the 1990s (Srivastava, 2007). These movements pushed for greater efficiency and sustainability in SC operations. As a result, GSCM began to integrate processes like green purchasing, reverse logistics, and collaboration across suppliers, manufacturers, and customers to enhance sustainability throughout the SC (Zhu and Sarkis, 2004). Sarkis *et al.* (2011) expand on this by defining GSCM as the integration of environmental considerations into inter-organizational practices of sustainable SCM. This includes processes such as reverse logistics, which focuses on managing product returns and waste, further reinforcing sustainability within SCs. Overall, GSCM remains a broad and evolving concept, with no single comprehensive definition. However, it consistently emphasizes the incorporation of environmental principles into SC activities, from sourcing to the end-of-life management of products, aiming to create more sustainable SC systems. In international business contexts, the adoption of GSCM must also account for institutional and cultural variations, making it essential for firms to align their environmental strategies with the regulatory and consumer expectations of each market (Zhong and Um, 2025).

2.1.2 Blockchain technology. BCT has been around since the inception of Bitcoin in 2009 (Schmidt and Wagner, 2019). To date, there is no single, universally accepted definition of BCT in academic circles. In the literature, it is often described as a specific type of distributed ledger technology. Because BCT operates on a peer-to-peer network with cryptographic signatures, there are no intermediaries between users (Esmaeilian *et al.*, 2020). Many researchers argue that BCT has the potential to revolutionize SC and operations management by rethinking, redesigning, and reshaping these fields (Long *et al.*, 2023). A BCT is a distributed data structure, also known as a distributed ledger, in which information is shared across a peer-to-peer network. Participants in the network, called nodes, communicate and verify data according to a pre-defined protocol, all without the need for a central authority. Distributed ledgers can be either decentralized, offering equal rights to all users, or centralized, granting specific rights to certain users (Esmaeilian *et al.*, 2020). Viewed through the lens of international marketing, BCT facilitates cross-border SC transparency and traceability, which can strengthen consumer confidence in sustainability claims while supporting compliance with varying regulatory frameworks (Mohamed *et al.*, 2024).

2.1.3 Green marketing performance. Marketing has been partially blamed for damaging the environment, as its activities have contributed to increased consumption and waste, while at the same time shortening product life cycles. This growing concern has led industry and marketing to recognize the importance of green marketing and to adapt their functions and strategies accordingly (Sharma, 2021).

There has been extensive research across disciplines on green marketing strategy, particularly concerning a firm's resource use. In the sustainability literature, green marketing is defined as marketing strategies, policies and processes that consciously address environmental concerns while aiming to generate revenue and achieve organizational and individual goals for a product or product line (Menon *et al.*, 1999). Leonidou *et al.* (2013) conceptualized green marketing programs as initiatives designed to achieve a firm's strategic and financial objectives while minimizing negative impacts or enhancing positive effects on the natural environment. However, in global markets, green marketing performance is shaped by how well firms adapt their sustainability messages and practices to different cultural values, consumer expectations, and environmental sensitivities (David *et al.*, 2025). This makes cross-border customization a key capability for international success.

In global markets, BCT-enabled traceability can support green brand positioning by offering verifiable sustainability credentials tailored to local regulatory expectations (Thompson and Rust, 2025). Especially in trust-sensitive environments, BCT acts not only as a data tool but also as a marketing asset, enhancing firm legitimacy and competitive appeal.

2.1.4 Environmental performance. There is a broad academic consensus that the assessment of environmental performance is a crucial metric for evaluating the sustainability of an organization's production processes (Lin *et al.*, 2024). Environmental performance refers to the interaction between an organization and the environment. It encompasses the environmental effects of resource consumption, the impacts of organizational processes, the environmental consequences of its products and services, the recovery and processing of those products, and compliance with environmental regulations (Dubey *et al.*, 2015). In global markets, firms face heterogeneous environmental standards and reporting frameworks that vary significantly across regions. As such, environmental performance extends beyond operational efficiency and emerges as a critical dimension of international marketing strategy (Doan and Vu, 2024).

2.1.5 Green technology innovation. GTI refers to a firm's ability to innovate by introducing new ideas that contribute to the development of new functional processes and products, as well as improving existing ones, with a focus on a more environmentally friendly approach (Castellano *et al.*, 2022). Feng *et al.* (2022) define it as any type of innovation that leads to or aims for substantial and measurable advancement toward sustainable development by minimizing environmental impacts, improving resilience to environmental challenges, or promoting the more efficient and responsible use of natural resources. Operating across borders requires firms to address diverse environmental standards and disclosure requirements. This makes environmental performance a strategic factor in shaping effective international marketing approaches, beyond its conventional operational role (Mahajan *et al.*, 2024).

2.2 Hypotheses development

2.2.1 Blockchain technology and green supply chain management. Duarte *et al.* (2020) explored the link between Industry 4.0 and green SCs, highlighting that Industry 4.0 builds upon foundational principles central to lean and green concepts. The integration of modern digital technologies (DTs) such as AI, pervasive computing, digital twins, 5G, augmented reality (AR), virtual reality (VR), advanced analytics, and distributed ledger technology is fundamentally transforming the way SCs are configured, coordinated, and managed (Mubarik and Khan, 2024). These advancements elevate SC processes, including planning, sourcing, manufacturing, and distribution, to unprecedented levels of efficiency and precision.

From the perspective of the PBV, the adoption of these digital technologies can be seen as a set of imitable and transferable practices. Companies that integrate DTs into their SCM operations can replicate processes that are widely available but can gain a competitive edge through the effective implementation of these practices (Bhandal *et al.*, 2022; Irfan *et al.*, 2022). However, performance outcomes will vary across firms depending on how well they adapt and integrate these technologies (Shankar and Gupta, 2024). Thus, while the practices themselves may be accessible to all firms, it is the capability to implement them strategically that determines superior performance in GSCM (Schmidt *et al.*, 2017).

On the other hand, the DCV emphasizes that firms must possess the ability to continuously adapt and reconfigure their resources and processes in response to evolving technological advancements and market conditions (Eisenhardt and Martin, 2000). The incorporation of DTs into SCM fosters process innovation, enhances relationships with key stakeholders, and improves responsiveness to business uncertainties (Mubarik *et al.*, 2024). These DCs allow firms to not only adopt cutting-edge technologies but also leverage them to create sustainable competitive advantages in rapidly changing environments (de la Torre and De la Vega, 2025). Given the transformative potential of BCT to improve SC processes and enhance environmental sustainability, its adoption is expected to positively influence GSCM practices.

While BCT enhances transparency, trust, and data integrity GSCM by facilitating traceability, regulatory compliance, and sustainability-driven decision-making (Longo *et al.*, 2017; Saberi *et al.*, 2019), its effectiveness depends on how firms strategically integrate it into their operations. From a DCV, firms adopting BCT can sense environmental risks, seize sustainability-driven opportunities, and reconfigure SC processes to enhance agility and resilience in the face of evolving regulatory and market pressures (Teece *et al.*, 1997; Wang *et al.*, 2019). Meanwhile, the PBV suggests that BCT institutionalizes sustainability practices by embedding automation, auditability, and trust-based governance into SC interactions, reinforcing collaborative and verifiable green practices (Feldman and Orlikowski, 2011). However, despite these theoretical advantages, several challenges may hinder the widespread adoption of BCT in GSCM. High energy consumption (Sedlmeir *et al.*, 2020), implementation costs (Queiroz *et al.*, 2020), and scalability constraints (Kshetri, 2018) create financial and operational barriers, particularly for firms in emerging economies. Moreover, the decentralized nature of BCT raises concerns over data privacy, interoperability, and information-sharing reluctance among SC actors, which may reduce its effectiveness in sustainability applications (Hughes *et al.*, 2019). While some studies emphasize BCT's role in strengthening green logistics, circular economy initiatives, and carbon footprint reduction, others highlight governance complexities, industry-specific adoption disparities, and long-term viability concerns (Saberi *et al.*, 2019; Sedlmeir *et al.*, 2020; Wang *et al.*, 2019). Given these contrasting perspectives, it is crucial to examine how firms leverage BCT to balance its sustainability benefits with its technological and economic constraints.

Accordingly, the following hypothesis is proposed:

H1. Blockchain technology positively influences green supply chain management.

2.2.2 Green supply chain management and green marketing performance. Improvements in organizational resources and capabilities are often reflected in improvements in various performance measures, including green marketing performance (Alzghoul *et al.*, 2024). In line with the RBV, which emphasizes value, rarity, inimitability and non-substitutability, the development of GSCM practices strengthens these attributes by fostering unique and hard-to-replicate capabilities (Sarkis *et al.*, 2011). Collaboration with customers on green initiatives has been shown to positively influence quality, flexibility and environmental outcomes, while partnerships with suppliers are associated with improved delivery performance (Ahmed *et al.*, 2023).

Furthermore, the RBV complements this by focusing on how the effective implementation of these green practices, including technological innovation, directly contributes to a firm's environmental and marketing performance (Zhong and Um, 2025). As suggested by Bromiley and Rau (2014), PBV highlights the critical role of specific practices, such as GSCM, in driving performance improvements. The synergy between GSCM and green marketing performance can be further supported by the fact that the adoption of sustainable practices is often reflected in marketing messages and campaigns. This, in turn, increases the credibility and attractiveness of a company's green initiatives to environmentally conscious consumers, providing a competitive advantage in markets that prioritize sustainability. PBV theory thus helps to explain how these operational green capabilities translate into tangible marketing outcomes, linking operational excellence with market-oriented performance (Wade and Hulland, 2004). Based on this reasoning, the following hypothesis is proposed:

H2. Green supply chain management positively influences green marketing performance.

2.2.3 Blockchain technology and green marketing performance. Organizations worldwide are increasingly adopting innovative technologies, such as BCT, to reduce their environmental footprint and enhance transparency in their operations. BCT has emerged as a key tool for advancing sustainability efforts by enabling firms to verify and communicate their environmental practices more effectively (Jan *et al.*, 2024). The ability of BCT to provide stakeholders with real-time, immutable data on sustainable sourcing, carbon footprints, and eco-friendly practices significantly enhances transparency across the SC. This level of transparency not only improves operational efficiency but also plays a crucial role in building stakeholder trust, which is a critical component of green marketing performance (Nygaard and Silkoset, 2023).

From a marketing perspective, BCT's capacity to verify environmental claims can strengthen consumer loyalty by providing greater authenticity and accountability (Mohamed *et al.*, 2024). In a market where greenwashing is a common concern, BCT allows firms to offer verifiable proof of their sustainability initiatives, enhancing their credibility with eco-conscious consumers. As consumers become more environmentally aware, the demand for transparency and traceability in the SC grows, and BCT provides firms with the tools to meet these demands while reinforcing their commitment to sustainability (Pattanayak *et al.*, 2024).

Moreover, digitalization through BCT can reduce the production threshold for green products by streamlining SC operations and lowering costs associated with eco-friendly practices (Singh *et al.*, 2024). This promotes green transformation by enabling firms to reach eco-conscious consumers more efficiently, improve product transparency, and communicate their sustainability efforts through more credible marketing campaigns (Peng *et al.*, 2024). The ability to seamlessly integrate BCT into marketing strategies thus allows firms to differentiate themselves in increasingly competitive green markets by enhancing their environmental credibility and consumer trust. Based on these considerations, the following hypothesis is suggested:

H3. Blockchain technology positively influences green marketing performance.

2.2.4 Green supply chain management and environmental performance. Research in SCM has consistently demonstrated that collaboration both within and across organizations can enhance various dimensions of business performance, including environmental outcomes. Recent studies emphasize the critical role of aligning environmental initiatives within the SC to achieve sustainability goals (Al-Sheyadi *et al.*, 2019). GSCM has emerged as a central approach for improving the environmental performance of SC operations. By adopting GSCM practices, organizations can significantly reduce their environmental impact while enhancing sustainability performance (Seman *et al.*, 2019).

Collaboration with suppliers and customers is a key element of GSCM, enabling firms to build strong relationships that support joint efforts toward environmental sustainability. Through such collaborations, firms can align environmental goals across the SC, improving resource efficiency, reducing emissions, and minimizing waste (Zhu *et al.*, 2007). This not only strengthens environmental performance but also enhances the firm's reputation for sustainability among stakeholders. GSCM is thus recognized as a critical corporate strategy for demonstrating accountability to shareholders while advancing environmental sustainability. By reducing environmental risks and minimizing negative impacts, GSCM aligns corporate profits with broader market objectives (Micheli *et al.*, 2020).

A key component of GSCM is green purchasing, which plays a crucial role in supporting manufacturers' environmental initiatives. Green purchasing aligns procurement practices with sustainability goals by ensuring that suppliers adhere to environmental standards (Yee *et al.*, 2021). This practice encourages manufacturers to source eco-friendly materials and adopt sustainable production processes, ultimately enhancing their environmental performance (Opoku, 2025). Moreover, green purchasing fosters collaboration between manufacturers and suppliers in designing upstream SC processes that address environmental challenges, such as reducing carbon emissions and minimizing waste generation (Zhu and Sarkis, 2004).

As awareness of environmental issues grows and demand for eco-friendly products rises, GSCM practices add value to products while helping organizations build strong environmental reputations (Mitra and Datta, 2014). This not only supports compliance with regulations but also provides a competitive advantage in markets where sustainability is a key purchasing criterion. Thus, GSCM practices contribute significantly to improving environmental performance by promoting sustainability throughout the SC (Seman *et al.*, 2019). These considerations lead to the following hypothesis:

H4. Green supply chain management positively influences environmental performance.

2.2.5 Blockchain technology and environmental performance. Unlike many other areas of business operations where BCT impact is more clearly defined, its environmental impact remains a subject of debate. Critics argue that BCT, particularly in its application to cryptocurrency mining, is environmentally unsustainable due to its high energy consumption, which often relies on non-renewable energy sources (Kouhizadeh and Sarkis, 2018; Truby, 2018). These concerns are particularly relevant in the context of BCT's use in industries where large-scale server farms and intensive computational processes are required. However, when efficiently applied in SCM and other business processes, BCT has the potential to significantly reduce carbon emissions, waste, and environmental harm. By enabling real-time tracking, minimizing paperwork, and automating processes, BCT can enhance decision-making and improve environmental outcomes (Saberi *et al.*, 2019).

BCT plays a leading role in supporting firms' sustainability efforts by providing traceability and transparency in environmentally critical processes such as carbon footprint monitoring, waste management, and sustainable sourcing (Jan *et al.*, 2024). This transparency enables firms to track the environmental impact of their operations across the SC, ensuring compliance with environmental regulations and enhancing accountability to stakeholders (Garcia-Torres *et al.*, 2024). For instance, BCT can facilitate the tracking of recycled materials, support the implementation of cleaner production methods, and improve the monitoring of green practices in administrative and operational processes (Kouhizadeh and Sarkis, 2018).

By utilizing BCT's ability to verify the authenticity of eco-friendly practices, organizations can reduce the risk of greenwashing while building trust with environmentally conscious consumers. Additionally, BCT can help firms achieve greater operational efficiency by streamlining SC processes, reducing waste, and optimizing the use of resources. These capabilities strengthen an organization's environmental performance by minimizing harmful emissions and pollutants (Lindell and Karagozoglu, 2001). Given the potential of BCT to enhance environmental sustainability, the following hypothesis is proposed:

H5. Blockchain technology positively influences environmental performance.

2.2.6 Mediating role of green technology innovation in the relationship between GSCM, environmental performance, and green marketing performance. GSCM practices play a crucial role in promoting both environmental performance and green marketing performance by encouraging the adoption of GTI. According to the PBV, firm performance variations are driven by the adoption of specific practices, defined as a set of activities that firms can replicate and execute effectively (Bromiley and Rau, 2014). GSCM practices, while accessible to many firms, create performance differences based on how well they are implemented and aligned with green innovations (Khan *et al.*, 2021). These practices help firms integrate sustainability into their operations by adopting technologies and processes aimed at reducing environmental impact and enhancing competitiveness.

In the context of environmental performance, GSCM practices enable firms to strengthen relationships with suppliers and customers to promote sustainability throughout the SC. GTI plays a mediating role in this relationship by providing firms with the necessary tools and processes to enhance their environmental impact. Although Driessen and Hillebrand (2013) suggest that green innovations may not always originate with the explicit goal of environmental improvement, they nonetheless result in significant environmental benefits, whether directly or indirectly (Schiederig *et al.*, 2012). GTI, such as energy-efficient production methods, waste reduction techniques, and eco-friendly product design, amplify the positive effects of GSCM practices by improving resource efficiency, reducing emissions, and minimizing waste. These innovations allow firms to convert GSCM initiatives into measurable environmental gains, thereby enhancing their sustainability performance (Seman *et al.*, 2019).

Similarly, in the context of green marketing performance, GTI acts as a crucial intermediary between GSCM practices and marketing outcomes. GSCM fosters the integration of environmentally sustainable practices into a firm's operations, which can then be leveraged through green innovations to improve market positioning and consumer engagement (Fontoura and Coelho, 2022). From a PBV perspective, green innovation, which includes environmentally sustainable technologies aimed at energy efficiency, pollution prevention, and eco-friendly product development, serves as a practice that is widely available and transferable across firms (Chen *et al.*, 2006). However, the competitive advantage arises from how effectively these innovations are implemented to enhance performance. Firms that successfully integrate GTI into their SCM not only boost their operational efficiency but also strengthen their green marketing performance by improving their brand image, increasing customer loyalty, and ensuring compliance with environmental regulations (Zhu and Sarkis, 2004).

By adopting GTI, firms enhance their ability to market environmentally friendly products and services, leading to differentiation in competitive markets where sustainability is a priority. These innovations help convert sustainable SCM practices into tangible marketing benefits, such as cost reduction, improved consumer perceptions, and greater market share (Kraus *et al.*, 2020). Thus, GTI serves as both a driver of environmental performance and a key enabler of green marketing performance by transforming GSCM initiatives into marketable, sustainable outcomes. This reasoning leads to the following two-part hypotheses:

H6a. Green technology innovation mediates the relationship between GSCM and environmental performance.

H6b. Green technology innovation mediates the relationship between GSCM and green marketing performance.

2.2.7 Mediating role of green technology innovation in the relationship between blockchain technology, environmental performance, and green marketing performance. BCT has gained significant attention for its potential to enhance both environmental and marketing performance by increasing transparency, resource efficiency, and trustworthiness in SC operations (Wu, 2025). Tawiah *et al.* (2022) highlight that BCT facilitates the more efficient use of energy and natural resources, enabling firms to achieve higher levels of environmental efficiency. From a PBV perspective, these resource-efficient practices are replicable across firms, but the degree of their success depends on the firm's ability to effectively implement them. While BCT adoption lays the groundwork for environmental efficiency, it is the integration of GTI that further amplifies these benefits, resulting in enhanced environmental performance (Mohamed *et al.*, 2024).

GTI serves as the mechanism through which BCT contributes to improved environmental outcomes. Lee *et al.* (2023) emphasize that green innovation involves the development of processes and products designed to minimize environmental harm while advancing sustainability objectives. From the perspective of the DCV, GTI enables firms to adapt, reconfigure, and realign their operations to meet evolving environmental challenges (Singh *et al.*, 2022). This innovation transforms BCT from merely a tool for operational efficiency into a dynamic driver of sustainability by enabling firms to better monitor, control, and reduce their environmental impact.

In this framework, GTI acts as a crucial intermediary between BCT adoption and environmental performance. While BCT provides the necessary infrastructure for resource efficiency, it is through green innovation that firms can fully realize the environmental benefits of BCT (Jan *et al.*, 2024). By integrating green innovation into BCT-enabled systems, firms are better positioned to reduce emissions, minimize waste, and optimize resource usage (Du *et al.*, 2024). Firms that successfully combine BCT with GTI are likely to achieve superior environmental performance, leveraging both best practices and DCs to align their operations with sustainability goals (Wicki and Hansen, 2019).

Similarly, the relationship between BCT and green marketing performance is mediated by GTI. BCT's ability to create secure and immutable records enhances operational transparency and strengthens trust between firms and stakeholders (Gligor *et al.*, 2022). From a PBV perspective, BCT can be seen as a set of transferable and imitable practices that promote greater transparency and efficiency across operations. However, simply adopting BCT is insufficient to drive superior marketing performance outcomes. GTI serves as the operational mechanism that translates BCT's transparency into meaningful sustainability practices and market advantages (Alazab and Alhyari, 2024).

Through the lens of DCV, firms that combine BCT with green innovation demonstrate greater agility in responding to changing environmental and market conditions. By operationalizing BCT's transparency and security features, GTI allows firms to convert these advantages into tangible marketing outcomes, such as enhanced consumer trust, improved brand reputation, and competitive advantage in environmentally conscious markets (Polas *et al.*, 2022). While the core practices associated with BCT may be accessible to all firms, PBV suggests that firms capable of leveraging BCT through innovative green technologies experience varying degrees of green marketing performance. Likewise, from a DCV perspective, firms that integrate and adapt new technologies like BCT and green innovation are better equipped to excel in eco-friendly markets, capturing greater market share through sustainability-focused marketing strategies (Verma and Diwan, 2024).

Thus, based on the PBV and DCV perspectives, GTI plays a pivotal role in translating the benefits of BCT into superior environmental and green marketing performance. Based on this reasoning, the following paired hypothesis is proposed:

H7a. Green technology innovation mediates the relationship between blockchain technology and environmental performance.

H7b. Green technology innovation mediates the relationship between blockchain technology and green marketing performance.

Figure 1 illustrates the proposed model along with the hypothesized relationships.

3. Methodology

3.1 Sample and data collection

The primary data for this study were collected through a structured questionnaire developed by adapting established measurement items from the existing literature. Data collection took place over a four-month period, from November 2023 to March 2024. The questionnaire was distributed to a carefully selected sample of firms actively engaged in green and digital transformation processes in Türkiye, aligning with the objectives of our study, which focuses on GSCM, BCT, and GTI.

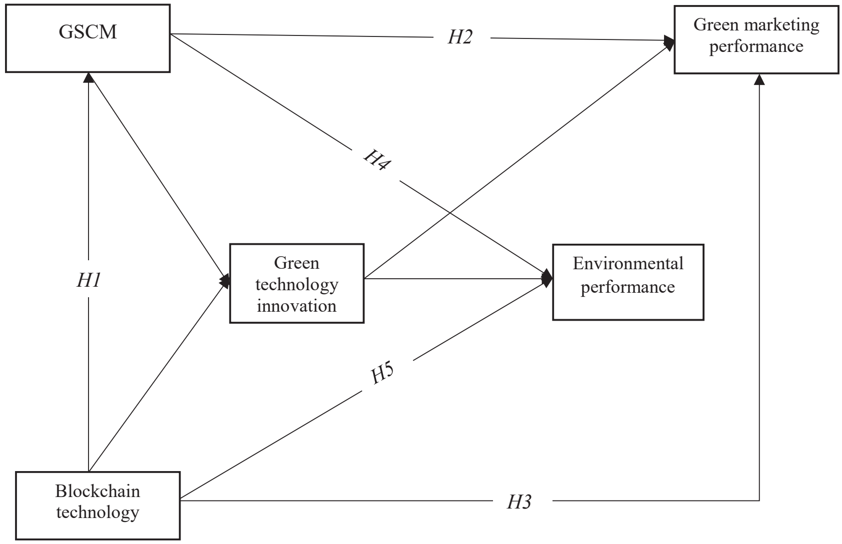

Figure 1. Proposed model. **Mediation hypotheses:** *H6a*: GSCM → Green technology innovation → Environmental performance; *H6b*: GSCM → Green technology innovation → Green marketing performance; *H7a*: Blockchain technology → Green technology innovation → Environmental performance; *H7b*: Blockchain technology → Green technology innovation → Green marketing performance. **Source:** Authors' own creation

The sample was drawn from 350 firms that are members of the Istanbul Chamber of Industry, selected through Yıldız Technical University's well-established Technology Transfer Office (TTO). Yıldız Technical University, as one of the largest technical universities in Istanbul, has strong industry ties and is home to the country's largest Technopark. This Technopark, coupled with the university's leading TTO, facilitates robust collaboration between academia and industry, particularly with firms that are at the forefront of technological and sustainability initiatives. Istanbul, as the leading industrial and commercial hub of Türkiye, serves as the ideal location for the selection of firms, ensuring that the sample is representative of the country's most innovative and strategically positioned companies.

The selection of firms for this study was strategically focused on those firms that are not only involved in the green and digital transformation but also exhibit a strong commitment to sustainability through initiatives such as BCT adoption, environmental sustainability programs, and the publication of sustainability reports. This sampling strategy ensured that the participating firms were well-aligned with the focus of our research, particularly in terms of their involvement in GSCM and their use of digital technologies to enhance sustainability.

The firms in the sample represented a diverse range of industries, including manufacturing, services, and technology, ensuring that the findings of the study are applicable across different sectors. The sample also included firms of varying sizes, from small and medium-sized enterprises (SMEs) to large corporations, to capture a broad spectrum of organizational practices and experiences related to GSCM and BCT. This diversity in both industry and firm size contributes to the generalizability of the study's findings and provides insights into how different types of organizations approach green and digital transformations.

To ensure the collection of high-quality data, all 350 firms were contacted via email and phone, specifically targeting general managers and senior executives responsible for strategic decision-making. These respondents were selected based on their extensive knowledge of their firms' green and digital initiatives and their active involvement in shaping and implementing these strategies. Ultimately, 93 firms agreed to participate, reflecting a cross-section of industries with varying levels of engagement in green initiatives. A total of 400 questionnaires were distributed, targeting 3 to 5 respondents per firm, and following two follow-up reminders, a final sample of 281 respondents was obtained. Selecting multiple respondents per firm enabled the capture of insights from diverse functional areas within each organization, offering a more comprehensive understanding of firm practices and minimizing potential bias. This multi-informant approach strengthens the validity of the data by offering a more comprehensive view of each firm's green and digital practices.

Respondents were carefully chosen from departments most relevant to the study's focus areas, ensuring that they possessed the necessary expertise to provide informed responses. The majority of respondents were drawn from marketing/sales (67%) and procurement (25%) departments, both of which are crucial to GSCM and BCT adoption. A smaller proportion came from finance (8%), reflecting the growing involvement of financial departments in sustainability initiatives due to the financial implications of green investments and environmental accountability.

In terms of job roles, the sample included managers (52%), specialists/assistant specialists (36%), and directors (12%), ensuring that the respondents had sufficient experience and authority to provide meaningful insights. Their roles in sustainability, BCT, and green innovation were key to the reliability of the data, as these individuals were responsible for implementing and managing the very processes central to our study. The professional expertise and experience of the respondents further underline the validity and depth of the data collected.

The demographic profile of the respondents was predominantly male (60%), with 40% female respondents, reflecting a relatively balanced gender distribution. The majority of respondents were aged 25 to 40 (75%), indicating a dynamic and highly engaged workforce with significant involvement in driving green and digital transformations within their firms. Educational qualifications were also notable, with 68% holding at least a bachelor's degree and 27% holding a master's degree, highlighting the respondents' high level of competency and specialization in their respective fields.

The firms included in the study ranged widely in size, with a notable representation of large firms, particularly those employing 5,000 or more employees. This diversity in firm size enables the study to examine how organizations of different scales approach the integration of GSCM practices and BCT, further enhancing the generalizability of the findings.

3.2 Measures

Perceptual measures were used to empirically test the study's hypotheses, employing multi-item scales that were adopted, modified, or developed based on prior research. The scales were structured as five-point Likert scales, ranging from 1 (strongly disagree) to 5 (strongly agree). Detailed information on the questionnaire items related to these variables, along with their sources, is presented in the Appendix.

Following the translation procedure recommended by Usunier (2011), the original questionnaire items were first developed in English and then translated into Turkish. To ensure semantic and conceptual equivalence, a back-translation into English was carried out by an independent bilingual research team. To address potential emic and etic issues, a pilot test was also conducted with selected participants, and necessary adjustments were made based on their feedback.

To enhance content validity, the questionnaire was pre-tested with industry experts as well as academics in marketing and operations management. This process led to clarifications, refinements, and the incorporation of expert recommendations into the final version of the survey.

3.2.1 Independent variables. The measurement of GSCM was based on the items adopted from Kara and Edinsel (2022). The second independent variable, BCT, was measured using items adopted from Long *et al.* (2023). In measuring BCT, the study adopted the definition provided by Treiblmaier (2018:547): "a digital, decentralized, and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamper-proof records".

3.2.2 Dependent variables. Green marketing performance was assessed using four items developed by Nath and Siepong (2022). Environmental performance was evaluated through nine items modified from the studies of Lin *et al.* (2024) and Yasin *et al.* (2023).

3.2.3 Mediator variable. GTI was measured using three items adapted from Sahoo *et al.* (2023).

3.2.4 Control variables. This study controlled for several firm-specific characteristics that could potentially influence the relationships between the independent and dependent variables. Industry type was included as a categorical variable, where 1 represented manufacturing firms and 2 represented service firms. This distinction is important as the nature of GSCM, BCT adoption, and environmental practices may vary significantly across industries.

Firm size was measured using a ratio scale based on the number of employees, which is a commonly used indicator of firm scale and operational complexity. Larger firms may have more resources to implement green technologies and digital transformation, which could influence their environmental and marketing performance.

Firm age was also included as a control variable, measured using a ratio scale based on the number of years the firm had been in operation. Older firms may have more established processes and resources for managing GSCM and digital transformations, while newer firms might be more agile in adopting innovations but lack legacy systems.

The questionnaire was pre-tested for content validity by industry experts in GSCM and BCT, as well as academics specializing in marketing and operations management. This combined effort led to the clarification of certain items, the resolution of specific issues and the incorporation of valuable recommendations into the final version of the survey.

3.3 Common method variance

To mitigate common method variance (CMV) in this research, we employed both procedural and statistical controls, following established recommendations in the literature (Podsakoff *et al.*, 2003).

For procedural control, several strategies were implemented during the data collection process. First, participants were clearly informed that there were no “right” or “wrong” answers to the questionnaire items, emphasizing that their honest opinions were most valuable for academic purposes. Additionally, participants were assured that their responses would remain confidential, and the data would be used solely for academic research. This assurance of confidentiality was designed to reduce potential social desirability bias or concerns about providing unfavorable answers, both of which could contribute to CMV.

Moreover, the surveys were administered anonymously, further encouraging honest and candid responses. Anonymity serves as a procedural safeguard against CMV, as it alleviates respondents’ concerns about judgment or repercussions. A pretest of the survey instrument was conducted to identify and resolve any ambiguous or unclear items, thereby ensuring that respondents could easily comprehend the questions and provide accurate responses. This refinement of the survey items reduced the likelihood of measurement errors that could contribute to CMV.

One of the key procedural remedies was the use of multiple respondents from each firm. Targeting 3 to 5 respondents per firm allowed data collection across different functional areas, such as marketing, procurement, and finance. This multi-informant approach mitigates the risk of CMV by reducing the reliance on a single individual’s responses, thereby providing a more comprehensive and representative view of the firm’s practices. This approach also helps to alleviate potential biases related to individual perceptions, such as social desirability or acquiescence bias, which can skew the results when data is collected from only one source (Chang *et al.*, 2010).

For statistical control, Harman’s single-factor test was applied to assess the extent of CMV in our data. This diagnostic technique involves loading all variables into an exploratory factor analysis to examine whether a single factor emerges or whether one general factor accounts for the majority of the covariance among the measures. The test results indicated that a single factor accounted for 36.49% of the total variance, well below the critical threshold of 50%, which would indicate significant CMV (Podsakoff *et al.*, 2003). These findings suggest that CMV is not a substantial issue in this study, as no single factor dominates the variance in the data.

While Harman's single-factor test is a widely used diagnostic tool, it is recognized for its limitations in detecting more subtle forms of CMV (Fuller *et al.*, 2016). Accordingly, the questionnaire also included reverse-coded items and varied response formats to further mitigate the risk of CMV. The combination of these procedural strategies and statistical testing provides confidence that CMV does not pose a significant threat to the validity of our results.

3.4 Endogeneity check

To address potential endogeneity concerns, which are common in studies of technology adoption and sustainable SCM practices, we first employed the Gaussian copula approach, as recommended in recent literature (Hult *et al.*, 2018). This method allows for the detection of endogeneity in nonlinear models estimated by PLS-SEM. Individual path tests revealed no significant endogeneity issues in the primary relationships examined: GSCM → environmental performance ($\beta = 0.014$, $p = 0.682$), BCT → GTI ($\beta = 0.021$, $p = 0.593$), and GTI → green marketing performance ($\beta = 0.076$, $p = 0.841$), supporting the robustness of our structural model.

Two-stage least squares (2SLS) estimation was also employed using an instrumental variable (IV) approach. This method is particularly useful for dealing with endogeneity due to omitted variable bias or reverse causality by introducing an instrumental variable that is theoretically related to the endogenous predictors but uncorrelated with the model's error terms. Drawing on recent research (e.g., Bag *et al.*, 2022; Zeng *et al.*, 2017), we identified firms' strategic orientation towards circular economy practices, referred to as circular economy capability, a theoretically sound and empirically relevant instrument (see Appendix for the measurement items). This construct is conceptually related to the likelihood of adopting BCT and GSCM, but unrelated to the outcome variable, green marketing performance, thus satisfying the relevance and exogeneity conditions for a valid instrument. In the first stage, circular economy capability was significantly associated with both BCT and GSCM, confirming the relevance of the instrument. In the second stage, the predicted values were used to estimate the main structural paths. The results remained statistically significant, indicating that our model is not biased by endogeneity and supporting the robustness and validity of our causal interpretations.

4. Data analysis and results

4.1 Reliability and validity of constructs

Given that the "firm" served as the unit of analysis, composite scores for the questionnaire items were aggregated prior to data analysis. To assess the reliability and validity of our measurement scales, encompassing 28 items across all constructs, a confirmatory factor analysis (CFA) using IBM SPSS AMOS version 28.0 was conducted. The CFA, performed as a single model, yielded a satisfactory overall model fit [$\chi^2(1800) = 3500.215$, comparative fit index (CFI) = 0.90, incremental fit index (IFI) = 0.91, Tucker-Lewis index (TLI) = 0.88, root mean square error of approximation (RMSEA) = 0.06, and parsimonious normed fit index (PNFI) = 0.76].

Regarding specific fit indices, although the TLI (0.88) falls slightly below the commonly accepted threshold of 0.90, it still lies within an acceptable range, as minor deviations are permissible, especially when accompanied by strong complementary indicators (Byrne, 2016; Hair *et al.*, 2010). The literature emphasizes that TLI values close to 0.90 are acceptable in complex structural models, provided other indices confirm overall model robustness (Hair *et al.*, 2010).

Additionally, our reported PNFI of 0.76 exceeds the widely accepted threshold of 0.50 recommended by Hooper *et al.* (2008). While PNFI values above 0.80 indicate superior parsimony, values close to this benchmark, such as our result of 0.76, are still indicative of acceptable model parsimony, particularly in comprehensive structural models involving multiple latent variables (Mulaik *et al.*, 1989). Given the inherent complexity of our theoretical framework, our PNFI result, combined with strong complementary indices (CFI = 0.90, IFI = 0.91, RMSEA = 0.06), supports the conclusion that our measurement model possesses both adequate parsimony and robust overall fit. Collectively, these fit indices confirm the reliability and validity of our measurement scales (Hu and Bentler, 1999).

Convergent validity was assessed by examining the standardized loadings of the items on their respective constructs, all of which exceeded the recommended threshold of 0.60, in line with Chin's (1998) guidelines. Additionally, Table 1 shows that all composite reliability (CR) and average variance extracted (AVE) values surpassed the thresholds of 0.70 and 0.50, respectively, as advised by Fornell and Larcker (1981). Furthermore, the Cronbach's alpha values for all variables ranged from 0.94 to 0.97, far exceeding the recommended minimum of 0.70, indicating acceptable reliability. Discriminant validity was also measured using the heterotrait–monotrait ratio (HTMT). Table 2 shows that all HTMT values were below the 0.85 threshold, as suggested by Henseler and Sarstedt (2013). Moreover, as illustrated in Table 2, the square roots of AVE for each construct were greater than the inter-construct correlations,

Table 1. Descriptive statistics, composite reliability (CR), average variance extracted (AVE)

Constructs	Mean	SD	Item	Loadings	CR	AVE	Cronbach alpha
Green supply chain management	3.53	1.11	GSM1	0.930	0.977	0.877	0.977
			GSM2	0.914			
			GSM3	0.932			
			GSM4	0.942			
			GSM5	0.956			
			GSM6	0.955			
			GSM7	0.926			
Blockchain technology	3.05	1.32	BC1	0.957	0.986	0.945	0.985
			BC2	0.973			
			BC3	0.971			
			BC4	0.983			
			BC5	0.975			
Green technology innovation	3.62	1.11	GT1	0.895	0.964	0.872	0.963
			GT2	0.959			
			GT3	0.942			
			GT4	0.949			
			GT5	0.921			
Green marketing performance	3.55	1.03	GMP1	0.900			
			GMP2	0.885	0.944	0.899	0.944
			GMP3	0.913			
			GMP4	0.949			
Environmental performance	3.73	1.14	EP1	0.912	0.968	0.793	0.967
			EP2	0.926			
			EP3	0.894			
			EP4	0.931			
			EP5	0.911			
			EP6	0.922			
			EP7	0.744			
			EP8	0.891			
			EP9	0.869			

Source(s): Authors' own creation

Table 2. Correlations, Fornell-Larcker, and HTMT ratio values

Variables	1	2	3	4	5
1. Blockchain technology	0.945	*0.570*	*0.607*	*0.598*	*0.697*
2. Environmental performance	0.556	0.792	*0.725*	*0.765*	*0.827*
3. Green marketing performance	0.586	0.694	0.899	*0.752*	*0.815*
4. Green supply chain management	0.588	0.744	0.728	0.878	*0.791*
5. Green technology innovation	0.680	0.798	0.716	0.790	0.872

Note(s): In accordance with Fornell-Larcker's criteria, the values in underline along the diagonal represent the square root of the AVE; the italicized values above the diagonal indicate the HTMT ratios; the values below the diagonal reflect the correlations between variables, all of which are significant at $p < 0.01$

Source(s): Authors' own creation

confirming appropriate discriminant validity based on the Fornell–Larcker criterion (Fornell and Larcker, 1981).

4.2 Structural model assessment

After confirming the reliability and validity of the measurement scales, the main model was analyzed using structural equation modeling (SEM) with AMOS. The measurement model demonstrated an acceptable fit to the data [$\chi^2(1765) = 3{,}726.39$, $\chi^2/\text{df} = 2.11$, CFI = 0.87, IFI = 0.87, TLI = 0.86, RMSEA = 0.06, PNFI = 0.73]. As noted earlier, although the CFI, IFI, and TLI values were slightly below the ideal threshold (0.90), the RMSEA (0.06) and χ^2/df (2.11) values, along with a satisfactory PNFI (0.73), indicate an overall acceptable model fit (Hair *et al.*, 2010; Hooper *et al.*, 2008).

Potential multicollinearity among the independent variables was assessed by examining variance inflation factors (VIFs). Given the conceptual interrelationships between BCT, GSCM, and GTI, as well as the multiple performance outcomes analyzed, it was essential to ensure that collinearity did not distort the results. The analysis revealed that all VIF values were less than the threshold of 3, indicating that multicollinearity was not a concern. These results confirm that the estimated effects of BCT, GSCM, and GTI on environmental and green marketing performance are distinct and not unduly influenced by high correlations among the predictors.

The results, as depicted in Figure 2, show that the relationship between BCT and GSCM was found to be positive and significant ($\beta = 0.58$, $p < 0.01$), providing strong support for H1. This suggests that the adoption of BCT significantly enhances the implementation of GSCM practices. The use of BCT likely improves traceability and transparency in the SC, which are vital for the effective implementation of GSCM.

The results indicate that GSCM positively influences green marketing performance ($\beta = 0.44$, $p < 0.01$), supporting H2. This implies that firms that adopt environmentally sustainable practices in their SCs are better positioned to communicate their sustainability efforts to consumers, which in turn enhances their marketing outcomes. This relationship highlights the strategic importance of GSCM in not only improving operational sustainability but also in driving positive market perceptions and brand image.

Contrary to expectations, the analysis shows that BCT did not significantly influence green marketing performance, and thus H3 was not supported. This lack of significance ($\beta = 0.13$, $p > 0.10$) suggests that while BCT may enhance SC transparency, it does not directly translate into improved marketing outcomes without the integration of other factors, such as customer engagement or a firm's ability to leverage BCT for marketing purposes.

The relationship between GSCM and environmental performance was positive and significant ($\beta = 0.31$, $p < 0.01$), providing strong support for H4. This indicates that firms with effective GSCM practices are more likely to achieve improved environmental outcomes, such as reduced

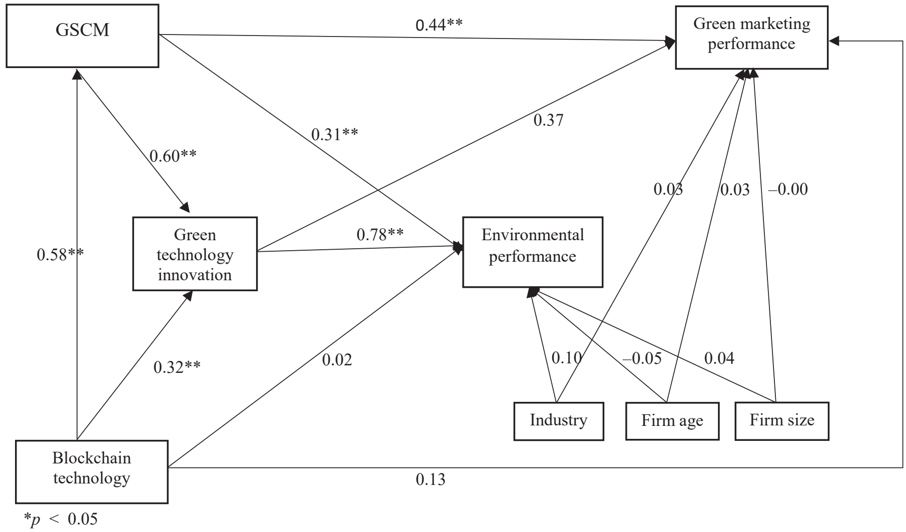

Figure 2. Results of path model. *$p < 0.05$ **Source:** Authors' own creation

emissions, waste, and resource use. This finding highlights the crucial role of sustainable SCM practices in directly contributing to a firm's overall environmental performance.

Lastly, the relationship between BCT and environmental performance was not significant ($\beta = 0.02$, $p > 0.10$), and therefore H5 was not supported. This result suggests that while BCT can enhance operational transparency and traceability, it does not directly impact environmental performance unless accompanied by other environmental initiatives or technologies. The lack of direct impact might be explained by the fact that BCT alone does not drive environmental improvements but rather facilitates the implementation of environmentally friendly practices when combined with other strategic initiatives.

Regarding the control variables, none of them, industry type, firm size, or firm age, were found to have a significant impact on either environmental performance or green marketing performance. This suggests that the relationships observed between GSCM, BCT, and performance outcomes are consistent across firms, regardless of their industry, size, or age. It also indicates that GSCM and BCT exert similar influences on sustainability and marketing outcomes, irrespective of these organizational characteristics. These findings indicate that the proposed model exhibits a certain level of generalizability across various organizational settings.

4.3 Mediation analysis

A mediation analysis was conducted to evaluate the role of GTI in mediating the relationships between the relevant variables. Mediation analysis provides deeper insights into the mechanisms underlying these relationships by showing how or why an independent variable influences a dependent variable (Hair *et al.*, 2006). In this study, mediation was explored to determine the extent to which GTI explains the relationship between GSCM, BCT, and the performance outcomes.

This study employed the PROCESS macro (Model 4) in IBM SPSS 28.0 to test the mediation hypotheses, utilizing a 95% bias-corrected confidence interval based on 5,000 bootstrap samples, in line with the guidelines outlined by Hayes (2017). While SEM was used to examine the overall structural model, Hayes' PROCESS macro was preferred for testing mediation due to its analytical strength in modelling causal mechanisms and indirect effects.

As Hayes and Rockwood (2020, pp. 48–49) note, researchers increasingly focus on understanding how effects operate and what influences their strength. Although some studies have suggested that combining SEM and PROCESS may be redundant (Memon *et al.*, 2018), the use of PROCESS in this study was justified by its robust bootstrapping capabilities and ease of interpretation in mediation analysis, which aligned closely with our research objectives. Specifically, we estimated path a (predictor to mediator), path b (mediator to outcome), and path c (predictor to outcome), and quantified the indirect effect as the product of paths a and b (ab). Given that the assumption of normality may not hold, a nonparametric bootstrapping procedure with 5,000 resamples was applied to compute bias-corrected 95% confidence intervals (CIs) for the indirect effects. Following Hayes (2017), mediation was considered significant if the CI did not include zero. Although there has been debate in the literature regarding the preferred method for mediation analysis (Pek and Hoyle, 2016), research has shown that observed variable SEM and OLS regression analyses tend to produce comparable results (Hayes *et al.*, 2017). For this study, the mediation models were estimated using the OLS method, in line with the recommendations of Coutts and Hayes (2023).

Based on the results presented in Table 3, several key mediation effects were identified. First, the mediation analysis of the relationship between GSCM, GTI, and environmental performance indicated full mediation. Specifically, the analysis showed a total effect of 0.677 ($p < 0.05$), a direct effect of 0.275 ($p < 0.05$), and an indirect effect of 0.442 ($p < 0.05$). The bootstrapped standard error (BootSE) was 0.119, with a BootLLCI (lower confidence interval) of 0.189 and a BootULCI (upper confidence interval) of 0.669, both positive. As the 95% confidence interval does not include zero, this confirms the presence of a significant mediation effect. The significance of both the direct and indirect effects suggests that GTI partially mediates the relationship between GSCM and environmental performance, providing strong support for H6a. This means that the impact of GSCM on environmental performance is entirely channeled through GTI, highlighting GTI's pivotal role in translating GSCM practices into tangible environmental outcomes.

In contrast, the mediation analysis did not identify a significant indirect effect in the relationship between GSCM, GTI, and green marketing performance. Specifically, the analysis of the mediation effect of GSCM on green marketing performance via GTI revealed a total effect of 0.517 ($p < 0.05$) and a direct effect of 0.334 ($p < 0.05$). However, the indirect effect was 0.216 and not statistically significant. The bootstrapped standard error (BootSE) for this effect was 0.214, with a BootLLCI (lower confidence interval) of −0.113 and a BootULCI (upper confidence interval) of 0.669. The presence of both positive and negative values within the confidence interval suggests that the indirect path is not consistently significant, as the inclusion of zero indicates a lack of statistical significance. Consequently, H6b is not supported, indicating that GTI does not mediate the relationship between GSCM and green marketing performance. This result underlines the complexity of the link between GSCM sustainability and marketing outcomes, suggesting that while GSCM practices may directly contribute to environmental performance, they may not necessarily enhance green marketing performance through GTI alone.

The analysis of the relationship between BCT, GTI, and environmental performance revealed evidence of full mediation. Specifically, when assessing the impact of BCT on environmental performance through GTI, the results indicated a total effect of 0.438 ($p < 0.05$), with a non-significant direct effect of 0.020. The indirect effect of 0.531 ($p < 0.05$) was significant, accompanied by a BootSE of 0.083. The BootLLCI of 0.362 and BootULCI of 0.684 fell entirely within the positive range, confirming the presence of a significant mediation effect, as the confidence interval does not include zero. Although the direct effect was not significant, the presence of a significant indirect effect supports full mediation, indicating that GTI fully channels the influence of BCT on environmental performance. Thus, H7a receives full support, highlighting that GTI plays a substantial role in linking BCT to improved environmental outcomes. This suggests that while BCT directly contributes to better environmental performance, a considerable portion of its impact is also facilitated through

Table 3. Mediating effects

Hypothesis	Total effect	Direct effect	Indirect effect	BootSE	BootLLCI	BootULCI	Level of support
H6a: GSCM → GTI → Environmental performance	0.677*	0.275*	0.442*	0.119	0.189	0.669	Supported (Partial)
H6b: GSCM → GTI → Green marketing performance	0.517*	0.334*	0.216	0.214	−0.113	0.669	Not supported
H7a: BCT → GTI → Environmental performance	0.437*	0.020	0.531*	0.083	0.362	0.684	Supported (Full)
H7b: BCT → GTI → Green marketing performance	0.326*	0.065	0.358*	0.108	0.148	0.578	Supported (Full)

Note(s): Bootstrapping $N = 5{,}000$; BootSE: Bootstrap standard error; BootLLCI: Bootstrap lower-level confidence interval; BootULCI: Bootstrap upper-level confidence interval
*$p < 0.05$
Source(s): Authors' own creation

GTI. In other words, BCT enhances environmental performance both directly and indirectly by fostering GTI. The full support for H7a implies that firms that utilize BCT for enhancing transparency and traceability can also gain additional benefits from the innovations that emerge as part of their broader sustainability initiatives.

Similarly, the mediation analysis of the relationship between BCT, GTI, and green marketing performance indicates full mediation. Specifically, when examining BCT's effect on green marketing performance through GTI, the analysis yielded a total effect of 0.326 ($p < 0.05$) alongside a non-significant direct effect of 0.065. The indirect effect was significant at 0.358 ($p < 0.05$) and accompanied by a BootSE of 0.108. The bootstrapped confidence intervals for this effect, with a BootLLCI of 0.148 and a BootULCI of 0.578, are entirely positive, indicating a consistent mediation effect. Given that the indirect effect is significant while the direct effect is not, this analysis suggests that GTI fully mediates the relationship between BCT and green marketing performance. Consequently, Hypothesis H7b is fully supported, highlighting that GTI plays a critical role in translating BCT initiatives into enhanced green marketing outcomes, though it does not fully account for the relationship. This finding implies that while BCT contributes to improved green marketing performance, much of the effect operates directly, with GTI serving as a supplementary mediator. Thus, organizations can leverage BCT to boost their green marketing efforts, yet the influence of GTI is recognized as secondary within this specific context.

4.4 Robustness check

To further ensure the robustness of the findings, a series of supplementary tests was conducted. First, we divided the dataset into two random subsamples and tested our model separately for each subset. The results demonstrated that the path coefficients remained stable across both samples, indicating that our findings are not sensitive to data partitioning. Second, following Sarstedt *et al.* (2020), non-linear effects were examined by incorporating quadratic terms for key variables. The results showed these effects to be insignificant, confirming the linearity of the model relationships and suggesting that the findings are not influenced by outliers or extreme values. Additionally, an alternative model specification was tested to further assess the robustness of the theoretical framework. In this specification, environmental performance was positioned as a mediator between GSCM and green marketing performance rather than as an independent predictor. The results showed that while environmental performance has a strong effect on green marketing performance, the direct effect of GSCM on green marketing performance remained significant, suggesting that environmental performance does not fully mediate this relationship. This further supports the validity of our proposed model structure. These robustness checks reinforce the stability and reliability of our findings, demonstrating that our conclusions hold across different sample conditions, alternative specifications, and model variations.

5. Discussion and implications

5.1 Theoretical implications

The relationship between GSCM practices and organizational performance has garnered increasing attention in academic research (Green *et al.*, 2012; Yu *et al.*, 2019; Zhu *et al.*, 2012), reflecting growing corporate awareness of the environmental and marketing benefits associated with sustainable practices. This study contributes to the literature by exploring the dual impact of GSCM on environmental performance and green marketing performance. Our findings affirm that the effective implementation of GSCM practices positively influences both a firm's environmental outcomes and its ability to market these initiatives credibly and effectively. This highlights the critical role of sustainable SCM in enhancing both environmental sustainability and market positioning (Behl *et al.*, 2023; Das, 2018; Li *et al.*, 2019). In summary, GSCM practices are not just operational or compliance-driven initiatives, but strategic resources that enhance a company's sustainability footprint and credibility in the marketplace. This study also enriches international marketing theory by showing how GSCM practices intersect with the complexities of global markets. Building on Steenkamp (2001), Johanson and Vahlne (2015), and Gereffi *et al.* (2005), our findings suggest that cultural differences, regulatory diversity, and varied consumer expectations shape the adoption and communication of BCT-enabled GSCM initiatives. Situating GSCM within these transnational marketing dynamics highlights that practices effective in one country may require adaptation to achieve similar impact in different cultural or regulatory settings.

A key theoretical contribution lies in the study's demonstration of the mediating role of GTI. By integrating the PBV with GSCM and GTI, the study advances a theoretical framework that elucidates how the implementation of widely accessible green practices can result in differential firm performance outcomes. The PBV lens allows us to understand how firms that effectively integrate green technologies into their operations are better positioned to achieve superior outcomes in both environmental and marketing dimensions (Sahoo *et al.*, 2023; Zhu *et al.*, 2012). Firms that align GTI with GSCM practices are likely to build competitive advantages, as this combination enhances both sustainability efforts and brand differentiation in increasingly eco-conscious markets.

An interesting outcome of this study is the finding that GTI does not mediate the relationship between GSCM and green marketing performance. This suggests that GSCM may exert a more direct influence on green marketing outcomes, independent of technological innovation. This finding is consistent with prior research indicating that the mediating role of technological innovation in the GSCM–performance link may vary by outcome type. For instance, Khan *et al.* (2022) found partial mediation for operational performance, suggesting that GSCM may directly influence green marketing performance without relying on GTI. The processes embedded within GSCM, such as reverse logistics, help firms manage product returns and waste effectively, offering a tangible demonstration of green practices that resonate with consumers. These processes directly support green marketing by providing concrete evidence of a firm's sustainability efforts, which can be leveraged in marketing communications. This finding also indicates that factors other than technological innovation, such as communication strategies, customer engagement, or regulatory compliance, may better explain the direct impact of GSCM on green marketing performance. Studies show that environmental dynamism and product-service innovation shape how GSCM improves organizational outcomes (Chaudhuri *et al.*, 2023). In addition, top management support and institutional pressure enhance the effectiveness of GSCM (Wen *et al.*, 2023), while customer collaboration and internal environmental practices also play a key role in enhancing green performance (Mughal *et al.*, 2023).

While our study hypothesized a significant mediating role of GTI between GSCM and green marketing performance, the results did not support this pathway. This non-significant finding invites further theoretical exploration. One plausible explanation is that GSCM practices may already be perceived by consumers and stakeholders as direct signals of environmental commitment, thus reducing the incremental marketing value added by GTI. Additionally, green technology innovations may be more relevant for internal process efficiency and compliance than for external stakeholder engagement unless explicitly communicated through integrated marketing strategies (Huang *et al.*, 2024). This finding suggests that firms may need to invest more in the communication and external validation of their green innovations to fully leverage their marketing potential (Chen *et al.*, 2025).

In contrast, GTI plays a significant mediating role in the relationship between GSCM and environmental performance, emphasizing its importance as a mechanism for achieving enhanced environmental outcomes. As noted by Lee *et al.* (2023), green innovations are critical for developing processes and products that minimize environmental harm while contributing to long-term sustainability goals. Our study reinforces this view by demonstrating that firms leveraging GTI within their GSCM frameworks are more likely to see substantial improvements in their environmental performance. However, the existing literature shows some mixed results. For example, while green innovations are often associated with improved environmental outcomes, their effectiveness may be limited by organizational capacity, weak institutional support or insufficient integration with broader sustainability strategies (Gelmez *et al.*, 2024). Similarly, studies suggest that in certain sectors, external pressures and regulatory gaps may prevent the full realization of the environmental benefits of GTI (Wen *et al.*, 2023). These mixed results suggest that uncontrolled contextual variables (e.g. corporate strategy, consumer perception or regional differences) may moderate the relationship between GSCM, GTI, and environmental performance. Moreover, the finding that GTI only partially mediates the link between BCT and both environmental and green marketing performance implies that BCT's impact may not be directly translated into outcomes without the organizational mechanisms necessary for innovation absorption. This supports prior arguments that BCT alone may not guarantee environmental or reputational gains unless integrated with innovation-driven change processes (Queiroz and Wamba, 2019; Tawiah *et al.*, 2022). Thus, while BCT provides the digital infrastructure, it is the activation of green innovation capabilities that ultimately converts technological potential into measurable environmental and marketing outcomes. Furthermore, the absence of a significant direct effect of BCT on green marketing performance, despite theoretical expectations, merits attention. One potential explanation is that the marketing benefits of BCT may materialize over longer timeframes or under conditions of higher consumer awareness and regulatory emphasis on transparency (Khan *et al.*, 2025). In markets where BCT-enabled claims are not yet fully understood or valued by consumers, the reputational advantages may not immediately translate into marketing performance (Duan and Zhu, 2024; Hina *et al.*, 2024). Future research could examine how the maturity of consumer perceptions or the extent of integration between BCT and marketing functions influences this relationship.

Furthermore, the study extends theoretical discussions on the role of BCT in sustainable SCs. The integration of digital technologies like BCT into SCM requires not only the adoption of available practices but also the DCs necessary to adapt and innovate in response to evolving technological and market conditions. Firms that effectively leverage BCT, coupled with strong DCs, are better equipped to respond to stakeholder demands, improve operational transparency, and enhance competitiveness in their GSCM operations. This research highlights that BCT, when used in conjunction with GSCM, can support firms in achieving superior environmental performance and market differentiation by providing greater traceability and trust throughout the SC. This role of BCT becomes even more critical in emerging economies such as Türkiye, where institutional volatility and resource constraints require greater adaptability and innovation capacity. As highlighted in previous studies, firms in these contexts rely heavily on DCs to align digital tools such as BCT with sustainability goals and to address regulatory complexity (Dubey *et al.*, 2020).

5.2 Managerial implications

Managers need to recognize the strategic importance of integrating GSCM with emerging digital technologies such as BCT to enhance both operational transparency and environmental performance. The implementation of BCT in GSCM allows companies to differentiate themselves in competitive markets by demonstrating their commitment to both sustainability and innovation. This can involve adopting principles of the circular economy, reducing resource consumption, and implementing renewable energy solutions. By leveraging BCT, managers can track and authenticate these sustainability innovations, ensuring that their green initiatives are both verifiable and credible. In emerging market contexts, where regulatory enforcement may be less consistent and stakeholder expectations more diverse, such digital verifiability becomes even more critical to building trust and legitimacy. By using BCT, managers can track and authenticate these sustainability innovations, ensuring that their green initiatives are both verifiable and credible.

BCT plays a crucial role in improving transparency within the SC by creating immutable records of transactions and environmental practices, which can add significant value to a company's green marketing narrative. In an era where consumers and stakeholders are increasingly skeptical of unverified environmental claims, the ability to provide data-backed proof of sustainability efforts is a powerful tool for building trust and credibility. Managers should focus on using BCT to monitor the implementation and effectiveness of green technologies within the SC, ensuring that environmental claims are not only accurate but also fully supported by verifiable data. This transparency can be leveraged in green marketing strategies, thereby enhancing the company's market positioning and reputation as a sustainability leader in an increasingly eco-conscious consumer market. For instance, integrating blockchain-generated sustainability certificates into product labels or marketing content can serve as tangible proof of green practices, offering consumers greater confidence and enhancing brand authenticity. For international marketing practitioners, it is equally important to tailor green marketing communications to reflect local cultural values and environmental concerns, while also managing BCT-enabled transparency across diverse regulatory and institutional environments. Firms operating across multiple markets must present their sustainability claims in ways that are both credible and aligned with the cultural values and contextual realities of each target environment. In addition to transparency, combining GSCM with GTI enables firms to meet their environmental objectives while also improving their brand image and corporate reputation. By effectively integrating these elements, companies can generate long-term value across both their operational and marketing functions. Managers should recognize that sustainability is not just a compliance requirement but a strategic differentiator that can drive competitive advantage, especially as global markets increasingly prioritize environmental performance. Firms that demonstrate leadership in sustainability are more likely to attract environmentally conscious consumers, enhance investor confidence, and cultivate long-term stakeholder loyalty. While such implementations may involve initial investments and organizational adaptation, they often yield long-term economic benefits through cost efficiencies, improved risk management, and expanded market opportunities.

For managers in emerging country markets such as Türkiye, leveraging BCT and GTI presents unique opportunities to overcome challenges like economic volatility, regulatory uncertainties, and limited access to advanced technologies. Despite these challenges, there is increasing pressure from global partners and consumers to prioritize environmental performance. Turkish firms can utilize BCT-enabled GTI to build a competitive edge, not only by improving their environmental footprint but also by enhancing their marketability in the growing green markets. By embracing these technologies, companies in emerging country markets can drive sustainable growth, improve operational efficiency, and build stronger global partnerships with environmentally conscious organizations.

Managers must also recognize the broader implications of this shift toward digital sustainability. The ability to monitor, verify, and report environmental initiatives in real time through BCT empowers firms to meet regulatory demands more efficiently and provides them with a reputation for accountability. By embracing this digital transformation, managers can position their firms as proactive leaders in the transition to a sustainable economy, ensuring that they remain competitive in both domestic and international markets. Managers operating across multiple countries should also adapt BCT-enabled green marketing strategies to different cultural values, regulatory regimes, and consumer expectations to maximize competitive advantage in international markets.

5.3 Limitations and future research

This study was undertaken in Türkiye, which may introduce contextual constraints. The findings may not be directly applicable to countries with distinct institutional structures, regulatory environments, or cultural attitudes toward sustainability. The national landscape in Türkiye, including evolving environmental regulations and cultural views on ecological responsibility, may have shaped how firms implement and benefit from GSCM, BCT, and GTI. Future studies should consider extending the investigation to other emerging economies to assess the broader applicability of these findings. Comparative analyses between countries with different regulatory frameworks, consumer awareness levels, and institutional maturity could provide valuable insights into conditions that enhance or limit the effectiveness of sustainability-oriented strategies. It would also be worthwhile to examine how marketing environments in export markets, including consumer expectations, communication standards, and compliance demands, influence the success of BCT-supported GSCM initiatives across borders.

While the study applied advanced econometric techniques, including two-stage least squares and Gaussian copula correction, the possibility of reverse causality cannot be fully eliminated. For example, firms already performing well in environmental metrics might be more inclined to adopt emerging technologies. Longitudinal research designs or panel data could help clarify the direction and magnitude of causal relationships. In addition, although a multi-informant approach was adopted to strengthen internal validity, the analysis did not explore potential perceptual variation across functional units within the same organization. Future research may delve into differences between departments to capture the diversity of internal views on environmental and technological strategy.

Another limitation is the cross-sectional nature of the research design, which restricts the ability to capture temporal changes in GSCM, BCT, and GTI adoption. Longitudinal studies could provide deeper insights into how these capabilities evolve, interact, and influence firm performance over time, particularly during external disruptions or in response to regulatory transitions. Tracking these developments across time may also help identify whether early-stage adoption yields compounding benefits or requires sustained investment to deliver results.

The current model examined only one mediating mechanism, namely GTI. Future research could broaden the conceptual framework by incorporating other explanatory pathways, including organizational culture, innovation climate, or employee involvement. It may also be valuable to examine variables that condition the strength of these relationships. Factors such as firm size, ownership structure, supply chain design, or technological readiness may moderate the outcomes associated with sustainability initiatives.

There is also scope to further explore the financial implications of investing in GSCM and GTI. Although environmental and marketing outcomes are increasingly studied, empirical research on financial performance remains limited. Future investigations could focus on cost savings, investment returns, or market competitiveness linked to sustainability strategies. Additionally, macro-level forces including government incentives, public policy shifts, and changing consumer behavior should be considered, as these external elements often shape the feasibility and success of green innovations.

Further research may also benefit from the application of international marketing frameworks to evaluate how institutional differences across national boundaries affect the relevance and success of GSCM and BCT adoption. Studies that assess adaptation strategies in different regulatory and cultural settings would help clarify the global potential of these initiatives.

Finally, future work could examine sectoral differences in sustainability and technology integration. Industry-specific studies could identify which sectors are more responsive to BCT and GTI, and which ones face structural or strategic barriers. It would also be valuable to investigate how consumers respond to sustainability claims that are verified by BCT, especially in relation to trust, credibility, and purchasing behavior. These insights would help marketers refine strategies that aim to communicate authenticity and build long-term loyalty.

5.4 Conclusion

This study emphasizes the growing importance of integrating GSCM with BCT and GTI to enhance both environmental and marketing performance. The findings contribute to the broader understanding of how digital technologies can drive sustainability initiatives, offering new perspectives on the strategic alignment of green practices. By leveraging BCT, firms can enhance transparency and credibility, while GTI provides a critical mechanism for achieving substantial environmental improvements.

Beyond the immediate implications, these results emphasize the importance of DCs in adapting to an evolving sustainability landscape. Firms that strategically adopt both technological and green innovations are better positioned to meet regulatory demands, improve stakeholder trust, and gain a competitive edge in increasingly eco-conscious markets. The study highlights the need for further research into how these relationships evolve over time, particularly as external factors such as government policies and market dynamics continue to influence sustainability practices.

Looking forward, the integration of GSCM, BCT, and GTI offers significant potential for businesses seeking long-term value creation through sustainable initiatives. Managers should focus on aligning these elements to drive both operational efficiency and market differentiation. For researchers, exploring the longitudinal impact of these technologies and practices on financial and operational outcomes, as well as conducting cross-industry comparisons, will provide deeper insights into the full potential of digital sustainability transformations.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Halit Keskin, Ali Ekber Akgün, Emel Esen and Ekrem Tatoglu. The first draft of the manuscript was written by Halit Keskin, Ekrem Tatoglu and Emel Esen and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability

The data that support the findings of this research are available from the corresponding author upon reasonable request.

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Appendix

Table A1. Survey measures

Construct	Items	Source(s)
Green supply chain management	(1) We provide our suppliers with comprehensive information to support their compliance with our environmental requirements (2) We collaborate with our suppliers to jointly develop environmentally-conscious products (3) We formally assess our suppliers' environmental performance through a green procurement process (4) We require our suppliers to establish environmental management systems (5) We require our suppliers to develop more environmentally-friendly products (6) We conduct regular environmental audits of our suppliers (7) We offer technical, managerial, and financial support to our suppliers to help them address environmental challenges	Kara and Edinsel (2022)
Blockchain technology	(1) We utilize distributed ledger technology to facilitate information sharing with our SC partners (2) We employ distributed ledger technology to ensure the confidentiality, integrity, and availability of data (3) We leverage distributed ledger technology to enhance transparency across the SC. (4) We routinely use distributed ledger technology as a platform to trace the origins, usage, and destinations of products (5) We consistently utilize distributed ledger technology to mitigate the risks of unreliable information	Long *et al.* (2023)
Green marketing performance	(1) We achieve increased sales from our green products (2) We achieve an increased market share for our green products (3) We achieve a higher return on investment (ROI) from our green product initiatives (4) We achieve a reduction in compliance costs related to our green products	Nath and Siepong (2022)
Environmental performance	(1) Our organization implements a policy of environmental sustainability in product development (2) Our company implements a policy of environmental sustainability in development processes (3) Our company applies sustainability practices committed to the welfare of employees, society, and the environment (4) Compared to our main competitors, our company reduces air emissions (5) Compared to our main competitors, our company reduces wastewater (6) Compared to our main competitors, our company reduces solid waste (7) Compared to our main competitors, our company decreases the consumption of hazardous, harmful, or toxic materials (8) Compared to our main competitors, our company reduces the frequency of environmental accidents (9) Compared to our main competitors, our company improves its overall environmental performance	Lin *et al.* (2024), Yasin *et al.* (2023)

(*continued*)

Table A1. Continued

Construct	Items	Source(s)
Green technology innovation	(1) Our company continuously optimizes manufacturing and operational processes by implementing cleaner methods or green technologies to achieve cost savings (2) Our company actively engages in the redesign and improvement of products or services to comply with environmental and regulatory requirements (3) Our company specializes in recycling practices to ensure the recovery and reuse of end-of-life products in new manufacturing processes	Sahoo *et al.* (2023)
Circular economy capability	(1) Our country promotes sustainable development through circular practices at the enterprise and consumer levels (2) Our company is committed to reducing raw material and energy consumption (3) Our company improves the energy efficiency of production equipment (4) Our product packaging is designed for repeated use (5) Waste from the manufacturing process is recycled (6) Post-consumer waste is collected and recycled (7) Reprocessed waste is used to produce new products	Bag *et al.* (2022), Zeng *et al.* (2017)

Source(s): Authors' own creation

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