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Green supply chain and sustainable development performance: evidence from the agricultural sector in the Mekong Delta

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Abstract: Growing environmental awareness and regulatory pressures have made green supply chain management (GSCM) a critical strategy for sustainable development, particularly in agriculture. This study examines the impact of GSCM on sustainable development performance in the Mekong Delta's agricultural sector. It aims to explore how GSCM practices influence economic, environmental, and social performance. Employing a mixed-methods approach, qualitative data were gathered through in-depth interviews with agricultural experts, while quantitative data were collected via a survey of 211 agricultural businesses in the Mekong Delta. The topic uses SmartPLS software to analyze Partial Least Squares Structural Equation Modeling (PLS-SEM). The results indicate that GSCM practices, especially green marketing and environmental education, considerably improve all three performance areas, with green marketing having the most significant effect (path coefficients: 0.370 for EP, 0.462 for EN, 0.441 for SP). In contrast, green manufacturing shows a less pronounced and statistically insignificant economic impact ($p = 0.068$), which is retained at a 0.1 significance level due to its long-term prospects. These findings highlight the vital role of GSCM in promoting sustainable development, specifically in reducing environmental impacts while enhancing economic and social advantages. Nevertheless, the study points out the economic difficulties faced by small and medium-sized enterprises (SMEs) and urges further investigation into addressing these challenges. The results provide practical insights for businesses and policymakers in the Mekong Delta to align with Vietnam's objective of achieving net-zero emissions by 2050, highlighting the transformative potential of GSCM in encouraging sustainable agricultural practices.

1 Introduction

Environmental protection awareness is on the rise, and businesses are experiencing significant pressure from both market forces and regulations imposed by customers and the government. In this context, green growth and sustainable development have become critical and unavoidable priorities, reflecting today's dominant trend [1]. Additionally, the national green growth strategy sets forth a thorough goal of fostering economic restructuring, linked with innovative growth models, social equity, and environmental sustainability [2]. Given these developments, green supply chains have transitioned from a mere trend to a necessity, involving practices such as eco-friendly production, green transportation, and sustainability in operations [3]. Currently, the Vietnamese government has announced ambitions to transform the country into a high-income nation by 2045 and achieve zero emissions by 2050. Embracing green and adaptable logistics practices will be crucial for lowering carbon footprints within the Vietnam logistics sector [4]. Therefore, pursuing green supply chains has shifted from a distant aspiration to an immediate necessity.

Most Vietnamese businesses recognize the significance of sustainable development for enhancing competitiveness and long-term success amid the rising trend of green consumption [5]. GSCM represents a proactive approach aimed at enhancing ecological outcomes consistent with regulatory standards [6]. Adopting a green strategy for resource management in the supply chain has become common, making environmental concerns and green supply chain practices key topics in numerous studies. This interest is evident in the initiatives taken by governments and organizations globally to mitigate their environmental impacts [7]. The goal of GSCM is to minimize the negative environmental consequences associated with products and services, starting from product design and the sourcing of eco-friendly materials through production processes to post-consumer waste management [8]. Consequently, many industries are progressively shifting towards GSCM to provide value for customers and stakeholders.

As environmental awareness grows, all stakeholders in the supply chain must integrate environmental considerations to enhance their performance. This focus on environmental and social improvement extends to the

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agricultural sector as well [1]. The Mekong Delta, known as Vietnam's most fertile agricultural area, relies heavily on agriculture, which constitutes 31% of the region's GDP. In 2023, it accounted for 50% of the country's rice production, 95% of rice exports, 65% of aquaculture output, 60% of fish exports, and roughly 70% of all fruit varieties (Mekong Delta region contributes roughly 31% to agricultural sector's GDP, 2024) [5]. However, climate change significantly affects the Mekong Delta, which is struggling with droughts, floods, riverbank and coastal erosion, and increasingly severe weather events. Agriculture, essential to the region's economy, is not exempt from these challenges. Consequently, this area is gradually shifting toward greener and more sustainable agricultural supply chain practices to reduce emissions and safeguard the environment [9].

Despite extensive research on GSCM in manufacturing and services, its application in agriculture, particularly in the Mekong Delta, remains underexplored [7]. This study addresses this gap by examining the impact of GSCM on economic, environmental, and social performance in the region's agricultural sector. Using a mixed-methods approach, it analyzes data from agricultural businesses to elucidate these relationships. The findings aim to advance GSCM theory in agriculture and provide practical insights for businesses and policymakers pursuing sustainable development in the Mekong Delta.

2 Theoretical background and hypothesis formulation

2.1 Green supply chain

The idea of a Green Supply Chain (GSC) emerged in the 1990s and gained momentum in 2000. A wealth of research has addressed GSCs, recognizing them as both a trend and a chance for businesses to enhance their competitive advantage [6]. Some scholars define the GSC as integrating environmental considerations. They assert that companies will utilize eco-friendly materials and convert them into outputs that can be reused or recycled, thus fostering a sustainable supply chain. This strategy can significantly reduce environmental harm [6,10]. Rupa & Saif [10] also describe the GSC as the melding of operational and logistical activities with environmental elements to promote long-term business growth. This means businesses must not only optimize their processes, such as purchasing and production, but also consider their environmental footprint [8]. Feng et al. [11] view the GSC as a pathway to bolstering environmental protection. They see it as a fully sustainable process encompassing procurement, manufacturing, distribution, marketing, and internal management. This implies that companies should consider environmental implications when making decisions.

Another viewpoint regards the GSC as a fusion of ecological awareness and supply chain management (SCM), covering product design, sourcing, material procurement, manufacturing, and distribution to end-users [8]. To achieve a truly green operation, businesses must train their employees and enact policies that enhance both operational efficiency and environmental impact [12]. The primary advantage of a GSC is improved resource efficiency and environmental protection [8]. Many logistics and transportation companies adopting GSC practices report reductions in energy usage and waste, alongside decreased packaging in distribution. Businesses are required to adhere to all environmental laws and regulations. For international organizations, adapting to new regulations can be a challenge [13]. However, compliance is necessary for continued operations. The real challenge lies in developing a flexible and responsive supply chain that can adapt swiftly while using minimal resources [7,8].

2.2 Sustainable development performance

Sustainable development is an ethical practice for businesses to shape their long-term growth. It refers to a developmental trajectory that balances economic welfare with environmental and social concerns [2,14]. These elements constitute the core dimensions of sustainable development, encompassing economic advancement, societal inclusion, and the safeguarding of natural resources [15]. While a universally accepted definition remains elusive, there is a shared understanding that any sustainable development framework must integrate economic, environmental, and social considerations alongside equity for both present and future generations [1,3]. Additionally, other scholars also view sustainable development as strategies that meet businesses' needs while safeguarding and maintaining natural resources and the environment [16].

According to the definition, a broad view of sustainability includes the concepts of economic, social, and environmental performance [17]. Within this context, in terms of SCM, environmental performance encompasses the reduction of pollutants emitted into the air, energy consumption, unsafe materials that negatively affect the environment, and adherence to environmental standards. Additionally, economic performance is defined as the improvements in financial and marketing performance that result from implementing GSCM practices, which enhance the firm's position relative to the industry average [3]. Financial improvements include reduced costs for material purchasing, energy usage, waste disposal, and environmental accidents. Enhancements driven by marketing efforts are reflected in better overall sales margins, improved profitability trends, stronger gains in business earnings, and broader expansion in market presence [17]. Lastly, Social performance encompasses the structure of a business's social responsibility, including its guiding principles, response strategies, implemented policies and programs, as well as the tangible outcomes that reflect the organization's interactions with society [1,2,15].

2.3 Green purchasing

Green purchasing involves using environmental criteria when selecting products or services. Also known as environmentally responsible procurement, it focuses on the deliberate selection and sourcing of goods and services that significantly reduce adverse ecological effects across their full life span, encompassing production, distribution, utilization, and end-of-life treatment [18]. In essence, green purchasing integrates environmental characteristics into traditional criteria, such as price and performance, during purchasing decisions [19]. Research indicates that green purchasing considers environmental factors alongside quality, cost, delivery, technology, service, and other strategically significant variables in procurement choices. Its main objective is to lessen the environmental impacts of sourcing while improving resource efficiency [20]. As a vital component of GSCM, green purchasing applies environmental analysis not only to a company's primary suppliers but also to those suppliers. This practice is crucial for mitigating the negative environmental impacts associated with manufacturing, usage, and recycling [21]. Additionally, it contributes to community health by promoting a cleaner environment, lowering health-related expenses, and fostering environmental sustainability. Furthermore, green purchasing strengthens dynamic and operational capabilities, positively influencing both environmental and economic performance, thereby advancing global sustainable development goals and bolstering stakeholder confidence [11].

Green purchasing is an environmentally responsible initiative that ensures the products or materials a company buys meet certain environmental goals. These include reducing waste, encouraging recycling and reuse, minimizing resource use, and substituting materials [12,21]. Moreover, it represents a company's commitment to conserving natural resources, maintaining ecosystem sustainability, preventing pollution, and reducing energy and water consumption. This approach motivates suppliers to develop environmentally sustainable materials and parts by working together, with a focus on minimizing waste, promoting recycling, and improving energy efficiency [21,22]. The importance of green purchasing stems from its focus on overseeing suppliers' environmental performance right from the beginning of the procurement process, thereby positioning purchasing as a key contributor to advancing sustainable resources and practices [23].

2.4 Green manufacturing

Green manufacturing contrasts with traditional manufacturing by prioritizing its environmental impact and adhering to national and international regulations about environmentalism [14]. Gupta et al. [12] characterizes green manufacturing as a framework that integrates design aspects of products and production processes with strategies for manufacturing coordination and oversight, with the goal of recognizing and mitigating environmental waste. This approach seeks to reduce environmental impact while maximizing resource efficiency. In essence, green manufacturing embodies environmental awareness [8,13]. Typically, activities such as remanufacturing, reusing, and recycling are the concepts of green manufacturing strategies, encompassing actions like decreasing hazardous waste, using environmentally friendly packaging materials, and determining suitable energy mixes for sustainable energy sourcing [18,23]. To achieve cleaner production, industries must implement environmentally conscientious operational policies across product development, manufacturing, service and distribution, and end-of-life processes, reflecting the growing focus on sustainability issues [11].

Green manufacturing can reduce energy costs, minimize waste treatment expenses, and prevent environmental fines. It also enhances a company's reputation, boosts its competitive edge, and improves overall performance [10,21]. While green manufacturing is gaining traction among businesses, many still struggle to measure its effectiveness. Besides that, some research has focused on implementing green manufacturing through specific strategies and success factors and addressing both technical and managerial challenges [8]. Overall, green manufacturing helps firms achieve greater success, competitiveness, and profitability. It represents more than a moral obligation; manufacturers acknowledge the long-term financial advantages of adopting environmentally responsible practices [14].

2.5 Internal environmental management

Susanty et al. [24] defines internal environmental management as a set of actions aimed at achieving a company's specific internal objectives, whether set by management or mandated by law. Other studies describe internal environmental management as positioning environmental sustainability as a central strategic goal, necessitating support and commitment from both senior and mid-level management [25]. Therefore, executing internal environmental management requires consistent monitoring and auditing, active senior leadership support, a willingness within the organization, and a collaborative culture [26]. It also promotes cooperation between various departments to enhance environmental performance and build systems. Recent research emphasizes the importance of internal environmental management across multiple functions, including purchasing, manufacturing, and inbound and outbound logistics, while also offering a comprehensive overview of ongoing discussions in this field [27].

Generally, all practices mentioned above are situated within the comprehensive framework of internal environmental governance [24]. A related term, green internal management, similarly conceptualizes this area by describing organizational practices aimed primarily at reducing their environmental impact. These practices involve policies, internal awareness, and adherence to environmentally mandated standards [26]. Moreover, targets for internal environmental management may also be set by supply chain entities, suggesting that environmental management must be integrated and coordinated throughout supply chain activities, rather than limited to individual companies [25,27]. The selected indicators for the internal environmental management framework are aligned with these requirements and include a dedication to GSCM, collaborative environmental efforts among departments, systems for environmental auditing, and adherence to environmental laws [26].

2.6 Environmental education

Environmental education is a crucial tool for fostering a sustainable society [28]. Palozzi et al. [29] describes it as a philosophy aimed at raising public awareness about environmental protection. This field encompasses a wide array of teaching methods, topics, audiences, and educators to educate people about the importance of the environment. This straightforward description highlights the various goals that environmental education will concentrate on, such as programs offering opportunities to engage with nature, learn about environmental issues, and acquire skills to protect, conserve, or restore the environment [30]. These resources help educators create learning experiences that enable students to gain knowledge, explore values, develop critical skills like questioning and problem-solving, and cultivate personal responsibility as engaged environmental citizens [28].

Environmental education is both complex and constantly advancing. Within the business context, its goal is to inform employees about the organization's ecological policies [31]. Environmental training enhances employee motivation and awareness regarding environmental challenges, cultivating the skills and knowledge necessary for making informed decisions and taking actions that reduce work-related environmental impacts. The results of such training include knowledge gain, shifts in attitudes, and changes in behavior toward the environment [30]. Learners are better equipped to acquire diverse environmental experiences and learn from real-world contexts that carry significant consequences as they encounter challenging social issues and misconceptions. To cultivate novel insights and forward-looking approaches, the learning process should be strategically integrated, foster transformative thinking, and enable the transition from personal knowledge acquisition to collective organizational learning [30,31].

2.7 Green marketing

Some scholars view green marketing as a form of ecological marketing, wherein companies focus on designing, advertising, pricing, and delivering goods that are environmentally safe [32]. It is a crucial element of the holistic marketing framework, especially relevant for industries that rely heavily on the physical environment, such as agriculture, production, tourism, and transportation, as environmental changes can threaten these sectors. Numerous global businesses across various industries are successfully adopting green marketing practices [22]. Researchers outline three steps in the development of green marketing. The first period, ecological marketing, focuses on addressing environmental issues through marketing efforts. The second period transitioned to environmental marketing, emphasizing clean technology for designing innovative products that tackle pollution and waste challenges. The final one, sustainable marketing, takes sustainability into account during product development [32].

Today, consumers are increasingly aware of environmental issues and becoming more responsible, leading companies to align with the demand for less harmful or neutral products. Many businesses seek early mover advantages, recognizing the necessity to adopt green practices [33]. Some benefits of green marketing include achieving long-term growth alongside profitability, realizing cost savings, promoting products with environmental considerations, entering new markets, and gaining a competitive edge. Additionally, employees often feel proud and responsible working for environmentally conscious companies. As a result, green marketing is one of the trends businesses should consider developing in the long term [32].

2.8 Green supply chain and economic performance

Green initiatives emphasize minimizing waste to support environmental sustainability. Reducing waste also directly contributes to lower costs and improves firms' economic performance [12,34]. Alkandi et al. [8] established a connection between GSCs and economic results, indicating that adopting GSC practices enhances competitiveness and boosts economic health. For instance, green purchasing decreases waste, promotes recycling, and encourages reuse, increasing business benefits. Additionally, green manufacturing can cut energy expenses, lower waste disposal costs, and avoid environmental penalties, while green marketing fosters long-term growth and profitability, emphasizing environmentally-friendly products [22,23]. Furthermore, internal environmental management and educational programs can positively influence economic outcomes by raising employee awareness of environmental protection, leading to higher profits for companies [28,34]. Overall, Rasheed et al. [35] research demonstrated that implementing GSCM significantly boosts firms' profitability, expands market share, and establishes a competitive advantage. Similarly, Hariharasudan et al. [6] explored the relationship between environmentally responsible practices and firms’ financial outcomes, revealing that incorporating such approaches into supply chain activities not only boosts profitability but also strengthens the organization's public image. Thus, the study proposes the following hypothesis:

Hypothesis H1: Green purchasing impacts economic performance.

Hypothesis H2: Green manufacturing impacts economic performance.

Hypothesis H3: Internal environmental management impacts economic performance.

Hypothesis H4: Environmental education impacts economic performance.

Hypothesis H5: Green marketing impacts economic performance.

2.9 Green supply chain and environmental performance

Rupa & Saif [10] conceptualized GSCM as a joint initiative among stakeholders that seeks to reduce the ecological footprint associated with production activities and end products. Recognized increasingly as a systematic and comprehensive approach, GSC practices are essential for achieving exceptional environmental performance. They facilitate the reduction of environmental damage through the joint efforts of suppliers, manufacturers, distributors, and customers working together to identify and prevent environmental issues [23]. A GSC is both economically viable and environmentally sustainable, as it emphasizes green material purchasing, eco-friendly production processes, and internal environmental management while considering the potential costs and benefits for all supply chain participants [3,21]. Additionally, GSC processes help minimize waste and emissions during production, transportation, and product usage by implementing eco-design, eco-packaging, and green marketing strategies [22]. These collective actions enable companies to lessen the negative environmental impacts linked to supply chain operations. Consequently, GSCM is deemed essential for a company's sustainable development and growth [34]. Overall, a GSC leads to enhanced environmental performance, particularly through environmental collaboration with customers. Thus, the study proposes the following hypothesis:

Hypothesis H6: Green purchasing impacts environmental performance.

Hypothesis H7: Green manufacturing impacts environmental performance.

Hypothesis H8: Internal environmental management impacts environmental performance.

Hypothesis H9: Environmental education impacts environmental performance.

Hypothesis H10: Green marketing impacts environmental performance.

2.10 Green supply chain and social performance

GSCM represents a vital direction in contemporary supply chain practices, playing a crucial role in economic activities. Its components encompass green procurement, green marketing, internal environmental management, environmental education, and green recycling, all of which influence social performance [21]. Assessing social performance presents difficulties because of the inherently subjective and non-quantifiable aspects of societal factors; for example, evaluating how a supply chain influences customer satisfaction or community well-being remains a complex task [23]. Although the concept of sustainable development encompasses economic, ecological, and social pillars, most existing research tends to emphasize the evaluation of ecological and financial outcomes [22]. Nevertheless, some researchers indicated that prioritizing social aspects can enhance business performance capabilities [34]. Furthermore, GSCs contribute positively to socially sustainable orientations and cultural performance, particularly in developed economies as well as in developing contexts [23,30]. Therefore, this study puts forth the following hypothesis:

Hypothesis H11: Green purchasing impacts social performance.

Hypothesis H12: Green manufacturing impacts social performance.

Hypothesis H13: Internal environmental management impacts social performance.

Hypothesis H14: Environmental education impacts social performance.

Hypothesis H15: Green marketing impacts social performance.

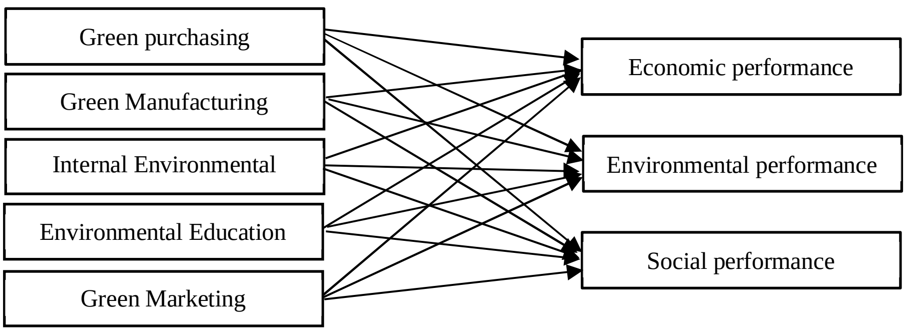

Figure 1 Proposed research model

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3 Methodology

This study adopts a mixed-methods research design, integrating qualitative and quantitative approaches to investigate the relationship between GSCM and sustainable development performance in the agricultural sector of the Mekong Delta, Vietnam. The exploratory phase was conducted using semi-structured discussions with 10 agricultural specialists and regional business executives to uncover critical GSCM elements influencing financial outcomes, ecological impact, and societal contributions. These insights informed the development of the research model and measurement scales. The quantitative phase employed a structured questionnaire, designed based on validated scales from prior literature [22,34], using a 5-point Likert scale to assess GSCM practices and performance outcomes.

Data were collected from agricultural businesses in the Mekong Delta, focusing on firms with experience in GSCM implementation. A pilot survey with 50 businesses was conducted to refine the questionnaire for clarity and reliability. The final survey, administered both in-person and online via Google Forms, yielded 219 responses, of which 211 were valid after data cleaning. The proportion of samples collected in the Mekong Delta provinces is as follows: An Giang (11.4%), Bac Lieu (6.6%), Ben Tre (3.8%), Ca Mau (7.6%), Can Tho (11.8%), Dong Thap (4.3%), Hau Giang (10.0%), Kien Giang (10.0%), Long An (7.1%), Soc Trang (0.5%), Tien Giang (10.4%), Tra Vinh (10.4%), Vinh Long (6.2%). Random sampling ensured representativeness across enterprise types (e.g., agricultural production, aquaculture) and sizes (87.6% SMEs).

Data analysis was performed using SPSS 26.0 for descriptive statistics and SmartPLS 3.0 for structural equation modeling (PLS-SEM). The measurement model was evaluated for reliability and validity through Cronbach's alpha (CA), composite reliability (CR), average variance extracted (AVE), and the Heterotrait-Monotrait (HTMT) ratio. All constructs met the thresholds (CA, CR > 0.7; AVE > 0.5; HTMT < 0.85). The structural model was assessed using path coefficients, R^2 values, and f^2 effect sizes, with model fit determined by Standardized Root Mean Square Residual (SRMR < 0.08) and Normed Fit Index (NFI > 0.8). A bootstrapping procedure employing 5,000 iterations was implemented to evaluate the validity of the proposed hypotheses ($p < 0.05$), thereby enhancing the reliability of statistical conclusions.

4 Results

4.1 Sample description

In terms of gender distribution, Table 1 shows there is almost an equal number of male and female respondents. In detail, 54.0% were male and 46.0% were female. The equal number of male and female survey participants indicates that the results are not gender-biased, ensuring that a wider variety of perspectives are represented. Such a gender balance can be seen as an advantage in the study given that both men and women play an active role across the supply chain in this Mekong Delta agricultural industry.

Table 1 Descriptive statistics of the research sample (N = 211)

Variables	Values	Frequency	Percent
Gender	Male	114	54.0
	Female	97	46.0
Position	Staff in charge	31	14.7
	Team leader/Supervisor	41	19.4
	Middle manager	90	42.7
	Senior executive	49	23.2
Work experience	Less than 5 years	7	3.3
	From 5 to 10 years	62	29.4
	From 11 to 15 years	85	40.3
	More than 15 years	57	27.0
Type of enterprise	Agricultural production and processing	175	40.8
	Forestry production and exploitation	88	20.5
	Aquaculture and seafood processing	162	37.8
	Other types of enterprises	4	0.9
Enterprise size	Fewer than 100 employees	106	50.2
	From 100 to 200 employees	79	37.4
	From 201 to 1,000 employees	21	10.0
	More than 1,000 employees	5	2.4

Job position: The survey sample reveals that the results are: Staff in charge (14.7%), Team leaders/supervisors (19.4%), Middle managers (42.7%), and Senior leaders (23.2%). The Majority of this at 65.9% is Middle managers and Senior leaders. This distribution fits the rationale for the research area of GSC and sustainable development, as this designation often has the final say over the implementation of green strategies.

The distribution of work experience is fairly uniform: less than 5 years (3.3%), 5–10 years (29.4%), 11–15 years (40.3%), and over 15 years (27.0%). A large portion of the respondents (67.3%) have over 10 years of experience, which suggests many people in the sample are seasoned professionals with significant insight into supply chain topics and sustainable development. However, the percentage of respondents with experience below 5 is very small (3.3%), which may lead to the opinions of young employees, who can provide them with different opinions on environmental and sustainable initiatives and technologies, being concealed.

Type of Enterprise: The sample includes enterprises operating in the following sectors: agricultural production and processing (40.8%), forestry production and exploitation (20.5%), seafood processing (37.8%), and other types of businesses (0.9%). This distribution appropriately reflects the economic characteristics of the Mekong Delta region, where agriculture and aquaculture play a dominant role.

Enterprise Size: The enterprise sizes are categorized into four groups: fewer than 100 employees (50.2%), between 100 and 200 employees (37.4%), between 201 and 1,000 employees (10.0%), and more than 1,000 employees (2.4%). This distribution shows that the sample is primarily composed of SMEs, with 87.6% of the businesses having fewer than 200 employees. This aligns with the actual business landscape in the Mekong Delta, where agricultural enterprises are mostly SMEs. However, the proportion of large enterprises (over 1,000 employees) is relatively low (2.4%), which may limit the representation of the role large firms play in GSCM and sustainable development, as these companies often possess greater resources to implement green practices.

4.2 Measurement model evaluation

The study evaluates the consistency and construct soundness of the measurement framework by thoroughly analyzing key metrics such as factor loadings, AVE, CR, and CA. The model is considered acceptable if the factor loadings are at least 0.7, the AVE is above 0.5, and the values for CR and CA exceed 0.7.

The analysis results indicate that all indicators exhibit factor loadings above the accepted threshold of 0.7, ranging from 0.752 (IE3) to 0.914 (GR2), except for GM6 and EE1, which fell below the required level and were consequently removed from the structural framework. This demonstrates that the chosen indicators are closely associated with their respective underlying constructs, thereby affirming the representativeness of the measurement instruments. Several indicators stand out with high factor loadings, such as GR2 (0.914 – Sponsoring environmental events), GR3 (0.913 – Updating environmental issues on the website), EE3 (0.910 – Environmental training programs), and GR4 (0.911 – Green image campaigns), highlighting the important role these activities play in measuring the concepts of Green Marketing and Environmental Education.

The results in Table 2 indicate that all variables in the model, GP, GM, IE, EE, GR, EP, EN, and SP, have CA and CR values exceeding the minimum threshold of 0.7. Specifically, the CA values range from 0.862 (GM) to 0.942 (GR), demonstrating that the internal consistency of the measurement scales is very good. The CR values range from 0.898 (GM) to 0.956 (GR), confirming that the composite reliability of the scales meets the required standard. These results indicate that the developed scales exhibit high consistency and are appropriate for measuring the concepts in this study.

The combined findings indicate that the AVE scores for every construct are above the acceptable minimum value of 0.5, with values spanning from 0.638 (GM) to 0.813 (GR). This demonstrates that the indicators within each variable explain the corresponding latent construct well, ensuring the model's convergent validity. Notably, the variable Green Marketing (GR) has the highest AVE value (0.813), indicating that indicators such as voluntarily providing environmental management information, sponsoring environmental events, updating environmental issues on the website, promoting green image campaigns, and focusing on environmentally friendly products effectively reflect the concept of GM in this study.

The VIF values of all indicators range from 1.454 (GM3) to 4.757 (GR4), remaining well under the commonly accepted cutoff of 5.0, which suggests the absence of significant multicollinearity among indicators within the same construct or between latent variables. However, some indicators within the GR variable show relatively high VIF values, such as GR4 (4.757), GR3 (4.429), and GR2 (4.148). This suggests that indicators like green image campaigns, updating the website on environmental issues and sponsoring environmental events may be highly correlated with one another, reflecting the fact that green marketing activities in the agricultural sector of the Mekong Delta are often implemented simultaneously.

Table 2 Measurement model evaluation

Variables	Indicators	Factor Loading	CA	CR	AVE	VIF
Green purchasing – GP	GP1. Provide suppliers with technical design specifications, including environmental requirements for the purchased items	0.768				1.768
	GP2. Acquired products are free from ecologically detrimental elements, including lead and other substances considered toxic or hazardous to the environment	0.816	0.894	0.922	0.704	2.234
	GP3. Conduct environmental assessments of the supplier's internal management	0.908				3.295

	GP4. Require suppliers to use environmentally friendly packaging (biodegradable and non-harmful)	0.847				2.350
	GP5. Materials are transported using fuel-efficient vehicles to reduce emissions	0.850				2.376
Green Manufacturing – GM	GM1. Supervise and manage ecological contaminants, including waste discharge	0.776	0.862	0.898	0.638	1.981
	GM2. Reduce noise pollution during the production process	0.753				1.857
	GM3. Control hazardous substances during production and the exploitation of available resources.	0.779				1.454
	GM4. Design processes focused on minimizing energy and natural resource consumption	0.840				2.561
	GM5. Recycle and reuse/recover materials, waste, or defective but valuable products in the production sector	0.841				2.693
Internal Environmental management – IE	IE1. Commitment of senior managers to GSCM	0.817	0.877	0.909	0.666	1.761
	IE2. Support from middle managers for GSCM	0.842				2.347
	IE3. Cross-functional collaboration to achieve environmental improvements	0.752				1.974
	IE4. Organizing workshops to raise environmental awareness	0.868				2.444
	IE5. Creating environmental reports for internal assessment	0.797				2.034
Environmental Education – EE	EE2. Natural environment workshops for senior executives/managers	0.895	0.874	0.922	0.798	2.593
	EE3. Environmental training and education programs for managers and staff	0.910				2.487
	EE4. Participation in government-sponsored natural environment programs	0.875				2.111
Green Marketing – GR	GR1. Regularly and voluntarily provide customers and organizations with information about environmental management	0.890	0.942	0.956	0.813	3.571
	GR2. Sponsor environmental events/collaborate with ecological organizations	0.914				4.148
	GR3. Periodically update the website with environmental issues	0.913				4.429
	GR4. Promote green image campaigns	0.911				4.757
	GR5. Consider eco-friendly products as a factor that drives customer purchase willingness	0.879				3.010
Economic performance – EP	EP1. Reduce/Minimize the cost of purchasing raw materials	0.851	0.907	0.931	0.730	2.370
	EP2. Reduce/Minimize energy consumption costs	0.855				2.420
	EP3. Reduce waste treatment and disposal costs	0.872				2.645
	EP4. Reduce fines for violating environmental regulations	0.824				2.181
	EP5. Reduce waste management costs	0.868				2.706
Environmental performance – EN	EN1. Reduce the emission of hazardous chemicals into air and water	0.873	0.892	0.921	0.700	2.828
	EN2. Reduce waste and recycle materials during the production process	0.848				2.469
	EN3. Enhance the company's environmental reputation	0.840				2.356
	EN4. Reduce the frequency of environmental accidents/incidents	0.855				2.464
	EN5. Reduce the consumption of harmful/toxic/hazardous materials	0.763				1.821
Social performance – SP	SP1. Employee health and workplace safety	0.829	0.878	0.916	0.732	1.988
	SP2. Contributions to social investment projects (education, culture, sports)	0.847				2.097
	SP3. Enhancement of public health and safety	0.889				2.708
	SP4. Minimization of the adverse impacts of products and processes on the local community	0.856				2.296

Table 3 presents the model fit indices, including SRMR, d_ULS, d_G, Chi-Square, and NFI, comparing the Saturated Model and the Estimated Model. The SRMR value of the estimated model is 0.075, which is below the commonly accepted threshold of 0.08 in SEM. This indicates a minor deviation between the actual and estimated covariance structures, implying an acceptable model fit. Compared to the saturated model (SRMR = 0.056), the SRMR value in the estimated model shows a modest increase, which is reasonable given that saturated models typically demonstrate superior fit owing to the lack of imposed structural restrictions. The d_ULS index of the estimated model is 3.926, significantly higher than that of the saturated model (2.219). The d_ULS measures the disparity between the actual and estimated covariance matrices based on the unweighted least squares method. A high d_ULS value in the estimated model suggests some degree of discrepancy between the actual data and the theoretical model. However, since there is no specific threshold for evaluating this index, it should be interpreted alongside other fit indicators. The d_G value for the estimated model is 0.995, compared to 0.808 in the saturated model. The d_G index assesses the geometric discrepancy between the model and the data. A d_G value close to 1.0 indicates a certain level of difference between the estimated model and the observed data but remains within an acceptable range. The Chi-Square value of the estimated model is 1134.394, higher than that of the saturated model (1057.082). In SEM analysis, the Chi-Square tends to increase with more complex models or larger sample sizes. The NFI of the estimated model is 0.807, slightly lower than that of the saturated model (0.820). NFI measures the improvement of the model compared to the null model. An NFI value ≥ 0.9 is typically considered good, while values between 0.8 and 0.9 are deemed acceptable.

Table 3 Model fit analysis

	Saturated Model	Estimated Model
SRMR	0.056	0.075
d_ULS	2.219	3.926
d_G	0.898	0.995
Chi-Square	1057.082	1134.394
NFI	0.820	0.807

The results of discriminant validity testing using the HTMT indicate that the conceptual constructs in the research model meet the acceptable reliability threshold. *Table 4* shows that all HTMT values are below the cut-off point of 0.85, except for the EN and SP pair, which recorded a value of 0.818. This finding demonstrates that the measurement variables in the model represent distinct concepts, with no evidence of content overlap. Overall, the results confirm the validity of the measurement model, making it appropriate for use in structural analysis to test the proposed research hypotheses.

Based on the analytical results using the Fornell-Larcker Criterion, as shown in *Table 5*, the model demonstrates satisfactory discriminant validity. Specifically, the square roots of the AVE, shown along the diagonal, are consistently greater than the correlation coefficients between each respective construct and all other elements within the model. This indicates a clear distinction between the variables. For instance, the square root of the AVE for EE is 0.893, exceeding its correlations with other variables, such as 0.297 with EN and 0.433 with EP. Overall, these findings confirm that the model meets the Fornell-Larcker Criterion, reinforcing the validity and reliability of the proposed research framework.

Table 4 Heterotrait-Monotrait ratio (HTMT)

	EE	EN	EP	GM	GP	GR	IE	SP
EE								
EN	0.333							
EP	0.483	0.584						
GM	0.054	0.252	0.118					
GP	0.237	0.417	0.417	0.065				
GR	0.091	0.476	0.345	0.075	0.082			
IE	0.302	0.443	0.505	0.070	0.606	0.049		
SP	0.373	0.818	0.637	0.239	0.360	0.458	0.416	

Table 5 Fornell-Larcker criterion

	EE	EN	EP	GM	GP	GR	IE	SP
EE	0.893							
EN	0.297	0.837						
EP	0.433	0.524	0.854					
GM	-0.011	0.236	-0.083	0.799				
GP	0.214	0.378	0.381	0.013	0.839			
GR	-0.078	0.439	0.321	0.058	-0.057	0.902		
IE	0.267	0.417	0.462	0.028	0.576	-0.021	0.816	
SP	0.330	0.724	0.567	0.229	0.325	0.418	0.385	0.856

R^2 reliability refers to the proportion of variance in the endogenous variables that is explained by the exogenous variables. The R^2 values range from 0 to 1, where values closer to 1 indicate a better model fit. Consequently, R^2 serves as a key indicator of the relationships between latent variables in the model and is a critical metric for evaluating structural models [35]. In this study, the R^2 values reflect a strong explanatory power of the model for the dependent variables. Specifically, the R^2 values for EN (0.498), EP (0.421), and SP (0.457) are within the medium to high range. This suggests that the variables in the model effectively account for a substantial portion of the variability in environmental performance, economic efficiency, and sustainable development in agricultural enterprises in the Mekong Delta region.

Table 6 R Square

	R Square	R Square Adjusted
EN	0.498	0.486
EP	0.421	0.410
SP	0.457	0.444

The f-square statistic measures the extent to which a particular exogenous variable contributes to the R^2 value of an endogenous construct. In other words, it evaluates how much of the previously unexplained variance becomes explained when the predictor is included in the model. As presented in Table 7, the f^2 value serves as an indicator of effect size. F-square value above 0.35 signifies a large effect, values between 0.15 and 0.35 indicate a medium effect, those between 0.02 and 0.15 reflect a small effect, and values below 0.02 are regarded as having no significant effect. Table 7 shows that the variable GR has the most prominent and significant impact on EN (0.421), EP (0.242), and SP (0.354), indicating that building sustainable relationships among supply chain partners is a key factor. Some variables such as EE and GP exhibit moderate effects, reflecting their supportive role in achieving performance objectives. Variables like IE and GM → SP show minor effects, highlighting the need for further investment and innovation to enhance practical effectiveness.

Table 7 f Square

	EE	EN	EP	GM	GP	GR	IE	SP
EE		0.093	0.252					0.126
EN								
EP								
GM		0.082	0.019					0.072
GP		0.063	0.168					0.031
GR		0.421	0.242					0.354
IE		0.071						0.060
SP								

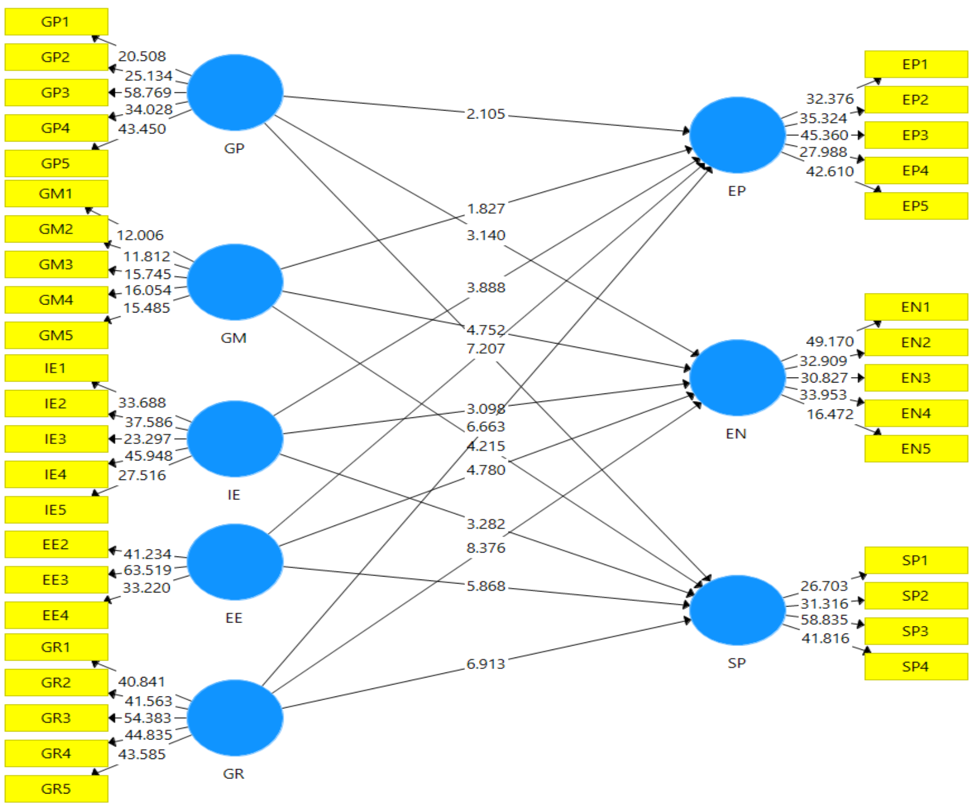

Figure 2 Structural equation modeling using PLS-SEM

The hypothesis testing results indicate that the components of GSCM have a significant impact on the sustainable performance of agri-businesses in the Mekong Delta. Specifically, 14 out of 15 relationships are statistically significant ($P < 0.05$), confirming the appropriateness and practical relevance of the proposed research model. Among these factors, GR demonstrates the strongest influence across all three performance dimensions: EP, EN, and SP, with path coefficients of 0.370, 0.462, and 0.441, respectively. EE also plays a crucial role, particularly in enhancing EP (0.349) and SP (0.273) (Table 8).

In contrast, GM does not exhibit a statistically significant effect on economic performance ($P = 0.068$), although it contributes positively to EN and SP. Other factors, such as GP and IE, show positive but comparatively weaker impacts. Overall, the findings highlight the pivotal role of green marketing and environmental education in promoting sustainable development.

Although the relationship GM -> EP has a P-value of 0.068 (> 0.05) and a path coefficient of -0.110, the author still chooses to retain this relationship at the 0.1 significance level for the following reasons:

- First, in social and economic research, especially in exploratory studies such as those on GSCs and sustainable development, it is common to adopt a statistical significance level of 0.1 ($\alpha = 0.1$) to identify potential relationships, rather than $\alpha = 0.05$. This approach aligns with the scope of this study, which is conducted in a novel context with limited data, such as the agricultural sector in the Mekong Delta, where research on GSCs remains relatively new. With a P-value of 0.068, the GM -> EP relationship is statistically significant at the $\alpha = 0.1$ level, suggesting there is a 90% probability that this relationship did not occur by chance.
- Second, GM in this study is defined to include activities such as pollution reduction (GM1, GM2), hazardous waste control (GM3), energy saving (GM4), and recycling (GM5). According to GSC theory, green manufacturing practices are expected to improve economic performance (EP) by reducing long-term costs (e.g., energy and waste treatment costs) and minimizing penalties related to environmental regulation violations (EP4). Although the path coefficient for GM -> EP is negative (-0.112), this does not necessarily negate the theoretical relevance of the relationship. The negative coefficient may reflect that in the short term, implementing green manufacturing requires high initial investments (e.g., purchasing clean equipment, staff training), which could temporarily impact economic performance negatively. However, in the long run, these practices are likely to generate significant economic benefits. Retaining the GM -> EP relationship at the 0.1 significance level allows the study to further explore the mechanism of this impact rather than dismissing it entirely.
- Third, the agricultural sector in the Mekong Delta faces numerous environmental challenges (such as pollution from fertilizers, pesticides, and aquaculture) and economic pressures (including high production costs and market competition). GM practices, such as pollution reduction and recycling, can help businesses lower waste treatment costs (EP3), save energy (EP2), and reduce environmental penalties (EP4), thereby improving economic performance in the long run. A P-value of 0.068 indicates that the GM -> EP relationship shows potential significance, especially considering that SMEs in the Mekong Delta (accounting for 87.6% of the research sample, according to Table 1) often have limited resources to implement green manufacturing. The negative coefficient (-0.112) may reflect the reality that the initial costs of implementing GM (e.g., investing in clean technologies) outweigh the immediate economic benefits. However, this does not imply that the relationship is unimportant. Retaining this relationship at the 0.1 significance level encourages further research into how to reduce the implementation costs of GM and, in turn, optimize its economic benefits.
- Fourth, the study sample size of $N = 211$ is relatively small for structural equation modeling (SEM), particularly with a complex model that includes multiple latent variables (GP, GM, IE, EE, GR, EP, EN, SP). With a small sample size, statistical tests (such as T statistics) may lack sufficient power to detect significant relationships at the 0.05 level, leading to the risk of eliminating potentially meaningful relationships. The P-value of 0.068 is very close to the 0.05 threshold, and if the sample size were larger (e.g., N = 300–400), the GM -> EP relationship might reach statistical significance at the 0.05 level. Therefore, retaining this relationship at the 0.1 significance level is reasonable to avoid overlooking a potentially meaningful relationship in the context of a small sample.

Table 8 Mean, STDEV, T-Values, P-Values

Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Hypothesis Results
GP -> EP	0.169	0.166	0.080	2.105	0.036	H1 (Accepted)
GM -> EP	***-0.110***	*-0.112*	*0.060*	*1.827*	*0.068*	*H2 (Accepted)*
IE -> EP	0.282	0.287	0.073	3.888	0.000	H3 (Accepted)
EE -> EP	0.349	0.350	0.048	7.207	0.000	H4 (Accepted)
GR -> EP	0.370	0.369	0.056	6.663	0.000	H5 (Accepted)
GP -> EN	0.224	0.224	0.071	3.140	0.002	H6 (Accepted)
GM -> EN	0.203	0.208	0.043	4.752	0.000	H7 (Accepted)
IE -> EN	0.228	0.229	0.074	3.098	0.002	H8 (Accepted)
EE -> EN	0.226	0.227	0.047	4.780	0.000	H9 (Accepted)
GR -> EN	0.462	0.460	0.055	8.376	0.000	H10 (Accepted)
GP -> SP	0.165	0.165	0.067	2.467	0.014	H11 (Accepted)
GM -> SP	0.198	0.201	0.047	4.215	0.000	H12 (Accepted)
IE -> SP	0.219	0.222	0.067	3.282	0.001	H13 (Accepted)
EE -> SP	0.273	0.272	0.047	5.868	0.000	H14 (Accepted)
GR -> SP	0.441	0.439	0.064	6.913	0.000	H15 (Accepted)

5 Discussion

The research results confirmed the important role of the GSC in promoting Sustainable Development Performance (SDP) across three aspects: Economic Performance (EP), Environmental Performance (EN), and Social Performance (SP) in the agricultural sector of the Mekong Delta. Specifically, 14 out of 15 relationships in the research model showed statistical significance at the 0.05 level, except for the relationship between Green Manufacturing (GM) and EP (P = 0.068). However, this relationship was retained at a significance level of 0.1, consistent with exploratory studies in the social and economic fields. Green Marketing (GR) stood out with the strongest impact on all three aspects (EN: 0.462, SP: 0.441, EP: 0.370), emphasizing that activities such as sponsoring environmental events, updating environmental information on websites, and building a green image can significantly promote sustainable development outcomes in the Mekong Delta, where awareness of environmental protection is increasing.

The relationship GM -> EP shows a negative coefficient (-0.112), which may reflect the fact that SMEs in the Mekong Delta (which make up 87.6% of the sample) face high initial investment costs when adopting green manufacturing, such as purchasing clean equipment or training employees, leading to a temporary negative impact on economic performance. However, GM still has a positive impact on EN (0.203) and SP (0.198), consistent with previous studies [22,23], demonstrating that green manufacturing is crucial in minimizing pollution and enhancing community safety. In addition, factors such as Environmental Education (EE) and Internal Environment (IE) also showed significant positive impacts, particularly EE with EP (0.349) and SP (0.273), emphasizing that environmental education can raise awareness and encourage sustainable behaviors, thus improving economic and social performance. This result reinforces the viewpoint of Bibi et al. [28] that environmental education is an essential tool for building a sustainable society.

The model showed an acceptable fit (SRMR = 0.075, NFI = 0.807), and the R Square values (EN: 0.498, SP: 0.457, EP: 0.421) indicated that the model explains the variation in sustainable performance aspects well, especially environmental performance. However, the R Square of EP (0.421) is the lowest, indicating that there are many other factors beyond the GSC affecting economic performance, such as market prices or the financial capacity of businesses. This result is consistent with the reality in the Mekong Delta, where the agricultural sector faces significant economic pressures (high production costs, market competition) and environmental challenges (pollution from fertilizers, aquaculture), making it necessary for green practices to take time to bring clear economic benefits.

6 Managerial implication and theoretical contribution

Managerial Implication: This study provides several practical implications for agricultural businesses in the Mekong Delta in adopting GSCs to promote sustainable development. First, given the strong impact of Green Marketing (GR) on all three performance aspects (EN, SP, EP), businesses should invest in green marketing activities such as sponsoring environmental events, building a green brand image, and promoting eco-friendly products. These efforts not only enhance environmental reputation but also strengthen economic and social benefits, especially as consumers are increasingly concerned about green products [6]. Second, Environmental Education (EE) has a significant impact on both EP and SP. Therefore, businesses should organize environmental training programs for employees and managers to raise awareness and promote sustainable behaviors, thereby improving economic and social performance. Third, although Green Manufacturing (GM) does not exhibit a statistically significant effect on EP at the 0.05 level, maintaining this relationship at the 0.1 level suggests the long-term potential of green production. Enterprises should collaborate with the government to receive support (e.g., subsidies, tax incentives) to reduce initial costs when implementing GM, thereby optimizing future economic benefits. Finally, the government and organizations in the Mekong Delta should develop specific support policies, such as subsidies for clean technology or technical training, to encourage SMEs to adopt GSCs, contributing to Vietnam's goal of achieving net-zero emissions by 2050 [4].

Theoretical Contribution: This study contributes to theory by clarifying the relationship between the GSC and sustainable development performance in the context of the agricultural sector in the Mekong Delta, an area that has been under-researched. First, the study confirms that GSC elements (GP, GM, IE, EE, GR) positively affect all three dimensions of sustainable performance (EP, EN, SP), complementing previous studies [8,34] and expanding the application of GSC theory to the agricultural field. Second, retaining the GM -> EP relationship at the 0.1 significance level offers a new perspective on the impact mechanism of green manufacturing, indicating that high initial costs may temporarily reduce economic performance, but the long-term benefits remain to be further explored. Third, the study highlights the prominent roles of Green Marketing and Environmental Education, contributing to theory by confirming that these factors influence not only environmental performance but also have strong effects on economic and social performance, especially in developing markets such as the Mekong Delta. Finally, this study provides empirical evidence of sustainable development performance in a region heavily affected by climate change, laying the foundation for further research on the relationship between GSCs and sustainable development across other industries.

7 Conclusions

The study confirmed that the GSC has a positive impact on sustainable development performance in the agricultural sector of the Mekong Delta, with 14 out of 15 relationships being statistically significant at the 0.05 threshold, and the GM -> EP relationship retained at the 0.1 significance level. GR and EE stood out with strong impacts on all three performance dimensions (EN, SP, EP), while GM demonstrated long-term potential despite its short-term negative effect on EP. The research model showed an acceptable fit (SRMR = 0.075, NFI = 0.807) and explained a substantial portion of variance in performance aspects (R Square: EN = 0.498, SP = 0.457, EP = 0.421), particularly in environmental performance.

The findings emphasize that adopting GSCs contributes to minimizing environmental impact while simultaneously enhancing economic and social performance, thereby supporting the Mekong Delta in addressing challenges related to climate change and economic pressure. However, due to the limited impact of GM on EP and the relatively lower explanatory power for EP, future research should consider additional mediating factors (such as government support policies) and increase sample size to improve the robustness of the results. This study not only provides a scientific foundation for encouraging businesses to adopt GSCs but also contributes to efforts toward achieving sustainable development goals in Vietnam, particularly in the context of the country's net-zero emissions target by 2050.

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