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The Impact of Green Supply Chain Management on Circular Economy Performance: The Mediating Roles of Green Innovations

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Abstract: *Background*: This study investigated the impact of green supply chain management (GSCM) on circular economy (CE) performance. The mediating roles of three green innovation types, namely green product innovation, green process innovation, and green management innovation, are also examined. *Methods*: This study's population comprised all companies in the manufacturing sector in Jordan. A simple random method was applied to gather data from 278 companies. The research model was evaluated in terms of validity and reliability, which were found to be satisfactory. Hayes's PROCESS macro in IBM SPSS was applied for hypothesis testing. *Results*: The findings showed that GSCM directly and positively affected CE performance. Moreover, GSCM showed positive impacts on the three types of green innovation. In addition, the three innovation types demonstrated positive impacts on CE performance and proved to positively mediate the GSCM–CE performance relationship. *Conclusions*: The present study is the first, to the best of our knowledge, to examine the mediating effect of green innovations on the GSCM–CE performance relationship. It is also among the first to examine the impact of GSCM on three different types of green innovation that represent technological and non-technological innovations.

Keywords: green supply chain management; green innovation; green product innovation; green process innovation; green management innovation; circular economy performance

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1. Introduction

The persistent pursuit of economic growth in an era of burgeoning environmental concerns and resource scarcity has generated a critical crossroads for businesses across the globe. Mounting pressure from governments, environmental groups, and concerned stakeholders demands a fundamental shift in corporate operations toward greater compliance with environmental regulations, minimizing the adverse consequences of manufacturing activities on the ecosystem [1]. This has increased the interest of manufacturing companies in adopting circular economy (CE) practices and enhancing CE performance [2–4]. The CE emerged as a new economic notion in contrast to a linear economy and was first acknowledged by Chinese companies [5]. CE performance attains sustainable consumption and production by means of a "cradle-to-cradle" concept [6]. Therefore, CE performance is evaluated in a technical cycle to boost the value of materials, which includes reducing, reusing, redistributing, remanufacturing, refurbishing, and recycling [7].

The switch from a linear economy to a CE entails companies redesigning their supply chains (SCs). Therefore, the CE is affected by the transition of the traditional SC to green supply chain management (GSCM) [8]. The extant literature points to GSCM as a prerequisite and one of the main drivers of CE performance [5,9–12]. However, a successful transition to a CE requires the adoption of innovative processes, production methods, and managerial activities to attain and sustain the desired CE performance [13–15]. Therefore, green innovations are deemed in the literature to be critical enablers of a CE since they rely on the introduction of new processes, products, and technologies [14,16].

Despite the increasing number of CE studies published in recent years, it remains an emerging concept that requires further insights from various perspectives, especially from the SCM perspective [9,17–19]. Also, research on CE performance is relatively new and developing, and further studies are needed regarding successful CE performance attainment and assessment, especially in emerging economies and developing nations [5,20–24]. However, few studies have investigated the links between GSCM and CE performance. Furthermore, to the best of our knowledge, no studies in the extant literature have examined the effect of green innovation as a variable that mediates the GSCM-CE performance relationship. Therefore, our study attempts to advance the literature by examining the direct impact of GSCM on CE performance and the indirect impact via three types of green innovations: green products, green processes, and green management innovations.

From the above perspective, the following research questions (RQs) have been raised:

RQ1. What impact does GSCM have on CE performance?

RQ2. What mediating role do green innovations play in the GSCM–CE performance relationship?

While this study delves into the intricate relationships between GSCM and CE performance, we acknowledge that this initial exploration serves as a foundation for future studies. Given the relatively recent nature of CE research, our findings represent a preliminary step toward a deeper understanding of the antecedents of CE performance. It is important to note that our study was conducted in a small developing country where the majority of manufacturing companies fall under the category of small- and medium-sized enterprises (SMEs). The awareness and implementation levels of CE principles in manufacturing SMEs in Jordan are still in their nascent stages. Moreover, the distinction between CE principles and CE performance indicators remains low for many managers in these SMEs. Additionally, we included manufacturing companies from various industries in the present study due to the limited number of companies belonging to a single industry type in Jordan. The understanding of the CE and its implementation levels notably varied across different industries. These contextual factors prompted us to utilize general indicators of CE performance that could be comprehensible and assessable by the targeted respondents. We recognize the need for future research to refine CE performance indicators, differentiating them from CE principles in more granular detail.

This paper is organized in the following manner: Section 2 includes a review of the related literature. Section 3 offers the theoretical background and the development of the study hypotheses. Next, Section 4 introduces the methodology. In Section 5, the results and hypotheses testing are provided. Finally, Section 6 includes the discussion, implications, and conclusions.

2. Literature Review

2.1. GSCM

GSCM originated as an innovative approach to SCs that pays attention to environmental sustainability by decreasing the negative impacts of manufacturing operations on the environment [1]. It was defined as "the set of SCM policies held, actions taken, and relationships formed in response to concerns related to the natural environment with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services" [25] (p. 69). Micheli et al. [26] defined GSCM as the incorporation of an environmental mindset throughout the SC, beginning with the design of the product and continuing through the sourcing of materials and components, the production and delivery of products to customers, and the product's end-of-life management. Hence, GSCM demonstrates how much environmental awareness is taken into account when designing and implementing SC operations [27]. GSCM attempts to eliminate or decrease waste, including hazardous chemicals, emissions, energy, and solid waste [28,29].

GSCM practices are divided into internal practices when direct control is within the company and operations involve internal stakeholders; external interorganizational practices are involved when operations involve external stakeholders [30]. While different GSCM practices have been used in prior research, this study conceptualizes GSCM using four practices: "internal environmental management (IEM), green purchasing (GP), cooperation with customers (CWC), and eco-design (ECD)". They were chosen because they are deemed the main practices in GSCM that have the possibility of minimizing the indirect and direct environmental effects of various of the company's SC processes [1,31]. They are also widely cited and have been used in prior studies [1,31–33].

IEM refers to intraorganizational routines, including management support, eco-auditing systems, environmental compliance plans, and cross-functional collaboration for environmental improvements [32]. GP considers environmental facets in purchasing policies, procedures, and programs [1]. Thus, GP ensures that purchased materials comply with green requirements, such as reusability and recyclability [32]. CWC refers to green cooperation with customers that considers customers' feedback about greening operations to better integrate environmental features into design, manufacturing, and packaging [31]. ECD describes the activities undertaken during the product development stage whose goal is to decrease the negative environmental effects of products throughout their entire life cycle [34].

2.2. Green Innovation

Researchers and practitioners have paid increasing attention to green innovation due to its critical role in achieving environmental sustainability in manufacturing processes [14,35]. Recently, governments, trade associations, public agencies, and other institutional stakeholders have shown increasing interest in reducing the negative environmental effects that business activities generate via green innovation [36]. The "Organization for Economic Co-operation and Development" [37] referred to green innovation as the implementation of new or notably enhanced products, processes, new organizational procedures, new marketing practices, external relations, or workplace organization. According to Rennings [38] (p. 3), green innovation is "the act of developing new ideas, behaviors, products, and processes that contribute to a reduction in environmental burdens or to ecologically specified sustainability targets".

In this study, green innovation is conceptualized considering three types widely used in the extant literature: green products, green processes, and green management innovations [38–46].

2.2.1. Green Product Innovation (GPRD)

GPRD describes the development of new goods or services with fewer environmental effects and less resource usage throughout their entire life cycle [47]. This type of innovation requires developing new, environmentally friendly products or improving existing products [48,49]. This entails enhancing the product's design and features to reduce negative environmental effects [50]. In relation to drivers of GPRD, research indicates that the main drivers include environmental management systems, regulations, cost savings, and market pull factors [45,51]. If consumers' awareness of environmental products is increased via eco-labels, the potential growth in demand will motivate GPRD [46].

2.2.2. Green Process Innovation (GPRC)

GPRC includes any change/adjustment within the manufacturing process that contributes to reducing negative environmental harm during the production stages [50]. The OECD [37] defines GPRC as the execution of new production/delivery processes with fewer environmental effects and less resource/energy usage. Horbach et al. [52] asserted that technological capabilities are considered the key drivers of adopting this type of innovation. Moreover, Triguero et al. [46] pointed out that GPRC may be initiated to comply with strict market requirements or to avert penalties and/or increased taxes. In addition, the better use of energy and materials that results in cost savings is seen as an essential reason for adopting GPRC [38].

2.2.3. Green Management Innovation (GMGT)

GMGT is concerned with new methods of management that boost green practices within organizations [53]. It is associated with managerial efforts to renew organizational routines, procedures, mechanisms, or systems to ultimately create eco-innovations [54]. GMGT can be attained via the introduction of management systems and organizational methods to deal with environmental issues in processes and products [48]. Via training courses, companies can provide employees with the knowledge and skills required to improve their creativity and promote an innovative atmosphere [55]. In particular, companies focusing on green training can provide their employees with environmental knowledge and skills and involve them in the process of management innovation [56]. GMGT not only minimizes environmental effects directly but also facilitates the implementation of green processes and product innovations [57].

2.3. Circular Economy Performance (CEP)

Several researchers have pointed out that the CE concept still has not reached its mature state in the academic literature since a standard definition does not exist. Kirchherr et al. [58] found that there are at least 114 definitions and explanations of the CE. However, the best-known definition, framed by the Ellen MacArthur Foundation (EMF), describes the CE as “an industrial economy that is restorative or regenerative by intention and design” [59] (p. 14). The CE was also defined as a “regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling” [2] (p. 3).

CE performance is the switch from “production–consumption–waste” behavior to “production–consumption–reuse” behavior [3]. It is generally recognized that CE performance is basically an environmental economy evaluation, which entails human economic practices in accord with the main 3R principles: reduce, reuse, and recycle. Reduce means minimizing the quantity of materials in the production and consumption stages; reuse is related to expanding the lifetime of products and services; and recycling emphasizes the regeneration of renewable resources after use [60]. Furthermore, Silva et al. [4] clarified that CEP practically refers to reuse in three stages: the product stage, such as refurbishing or repairing; the component stage, such as remanufacturing; and the material stage, which is considered recycling.

Recently, numerous indicators of CE performance have been proposed, but inconsistency exists in the literature regarding their scope, purpose, and possible application, as well as measuring these indicators at different levels (micro, meso, and macro) [61]. The current study is concerned with measuring CE performance at the micro level (company level). In this regard, the most widely used and cited indicators of CE performance, including minimizing the use of natural resources, minimizing emissions, minimizing losses of various components, raising the share of renewable and recyclable materials and components, and extending the value durability of products, are adopted in this study [20,61–63].

3. Theoretical Framework and Hypotheses Development

3.1. Research Framework

This study is based on the framework shown in Figure 1, which illustrates GSCM’s impact on green innovations and CE performance. Also, the impact of green innovations on CE performance is outlined. In addition, the mediation effects of green innovations on the GSCM–CE performance relationship are depicted.

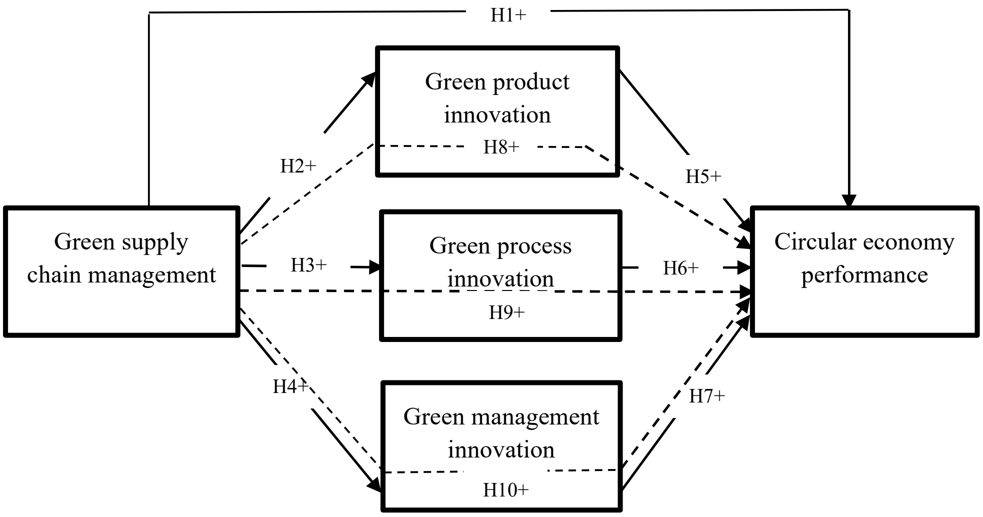

Figure 1. Research model.

3.2. GSCM and CE Performance

The transition from a traditional economy to a CE entails companies redesigning their SCs. Kazancoglu et al. [5] emphasized that when firms adopt GSCM, minimal resources are consumed, and environmental protection is achieved, leading to enhanced CE performance. In this sense, GSCM is proposed as a corporate strategy to achieve economic benefits, reduce negative environmental effects, and increase the efficient consumption of resources to attain greater CE performance [10]. Aminoff and Kettunen [9] asserted that GSCM is an essential driver of a CE. Other scholars have suggested the possibility of synergy between GSCM and CE [64,65]. GSCM includes the entire closed cycle of designing products, purchasing, processing, packaging, selling, using, and recycling. As a result, it involves each process of a product's life cycle, from cradle to cradle, resulting in improved CE performance [60]. To enhance CE performance, the implementation of GSCM should comply with key CE principles (3Rs) [60].

Zeng et al. [11] empirically found that sustainable SCM positively impacts CE capability in eco-industrial companies in China. Similarly, Zhu et al. [64] found that GSCM practices are beneficial and necessary antecedents for CE development in China. On the other hand, Zhu et al. [8] observed that firms that vary in their adoption of GSCM practices differ in their implementation of CE practices and attainment of CE performance. Thus, the following hypothesis is offered:

Hypothesis 1. *GSCM directly and positively impacts CE performance.*

3.3. GSCM and Green Innovations

As consumers worldwide show a greater inclination toward eco-friendly products, some manufacturing companies manage their GSCs so they can generate green innovations and produce more eco-friendly products [66]. Zhu et al. [64] emphasized that meeting consumer demand for eco-products is one of the main drivers for GSC participants to implement green innovations. For instance, gasoline consumption causes a significant amount of air pollution. As a result, electrical cars have been introduced as a green product innovation. Thus, an eco-design that balances the other measures of performance for consumer usage and demand is necessary to create a greener vehicle. Various companies realized that making their SCs green and adopting GSCM practices would likely lead to opening up new business opportunities related to green product innovations. Van Den Berg et al. [67] accentuated that firms are motivated to adopt green management innovations to minimize hazardous waste and emissions when they engage in green collaboration with SC partners. Such green collaboration is expected to increase the key green initiatives undertaken by management [68]. Green initiatives start with a senior management commitment and initiative, which is then translated into operations, such as adopting green process innovations [66]. Lee and Kim [69] demonstrated the essential role of green SC collaboration and showed that green supplier integration increases manufacturers' ability to successfully achieve green product innovation. Chiou et al. [70] also found that GSCM, in terms of greening suppliers, has a positive effect on green products, processes, and managerial innovations. Zhu et al. [12] found that GSCM is very effective in motivating companies to adopt advanced technologies and innovative management practices. Similarly, Chin et al. [71] considered GSCM to be the main driver of green innovation. Likewise, De Carvalho et al. [72] pointed out that GSCM and its environmental practices positively affect green technological innovation. Abu Seman et al. [73] revealed that GSCM positively affects green innovation in Malaysian manufacturing companies. In summary, the prior literature indicates that GSCM results in green innovation. Based on the aforementioned arguments, the following hypotheses are proposed:

Hypothesis 2. *GSCM positively impacts green product innovation.*

Hypothesis 3. *GSCM positively impacts green process innovation.*

Hypothesis 4. *GSCM positively impacts green management innovation.*

3.4. Green Innovations and CE Performance

Firms worldwide seek to transform their manufacturing processes and consumption behaviors to minimize material waste and produce environmentally friendly products [74]. Green innovations are considered key activities necessary to attain these objectives. This is because green innovations facilitate the ability to introduce new eco-friendly processes, products, and technologies and to introduce new business models. Therefore, they are expected to promote and enhance the CE performance of industrial firms [13,14]. At the company level, green innovations are associated directly with CE performance via green products or services, particularly in terms of a firm's resource efficiency [75]. Furthermore, it is essential to make fundamental changes to firms' processes and management systems. This would achieve a new form of environmental sustainability transition via the implementation and adoption of technological and non-technological green innovation mechanisms, which would allow firms to streamline CE performance [13,16]. Additionally, green innovations facilitate the process of reusing and remanufacturing products, resulting in enhanced CE performance. In essence, the cost of remanufacturing eco-products is ordinarily much lower than the cost of producing traditional components and materials [13]. Also, green innovations enable companies to apply new methods and procedures to decrease the economic and environmental costs of transportation, resulting in increased CE performance. Bag et al. [76] found that green innovation positively affected the CE of small and medium enterprises in South Africa. Maldonado-Guzmán et al. [14] demonstrated that green product, process, and management innovations had positive effects on CE performance in the automotive industry in Mexico. Therefore, the following hypotheses are proposed:

Hypothesis 5. *Green product innovation positively impacts CE performance.*

Hypothesis 6. *Green process innovation positively impacts CE performance.*

Hypothesis 7. *Green management innovation positively impacts CE performance.*

3.5. Green Innovations' Mediation Effects on the GSCM–CE Performance Relationship

According to the above literature and arguments, the implementation of GSCM can be expected to positively and directly impact CE performance. However, it is also important to evaluate the indirect influence of GSCM on CE performance via selected mediating variables to further contribute to the understanding of this relationship. In this vein, GSCM is expected to promote green innovations, which, in turn, will further enhance CE performance.

GSCM and green innovation are strategically linked. GSCM provides a solid base for industrial companies to cooperate with their suppliers, which has the potential to increase the activities associated with green innovation and improve green products and CE performance [67,69]. Enhanced green product innovation as a result of implementing GSCM practices enables firms to enhance their overall environmental goals and CE performance. Green process innovation encompasses all processes related to services and manufacturing that reduce negative environmental effects via specific measures, including energy conservation, waste recycling, and pollution prevention [77]. GSCM promotes green process innovation, resulting in a reduction in the resources used in production processes and energy consumption. Thus, green process innovation further enhances a company's CE performance. Furthermore, implementing GSCM by establishing an internal environmental management system results in enhanced green management innovation and leads to the constant development of systems that ensure the highest standards of the CE [8]. Additionally, training and managing employees so that they are part of the initiatives is expected to further increase CE performance. Del Giudice et al. [78] stated that to develop GSCM practices that boost the CE, a company must encourage the introduction of innovative solutions that ensure the sustainability of environmental and CE performance. This will require acting on multiple fronts to promote collaboration with external stakeholders in developing an SC that also has CE objectives.

In the prior literature, green innovation has been explored as a mediator. For instance, Abu Seman et al. [73] investigated the influence of green innovation as a mediator on the relationship between GSCM and environmental performance. Eiadat et al. [79] examined the mediating role of green innovation on environmental pressure forces and business performance relationships. In addition, Chang [80] investigated the mediating role of green innovation in corporate environmental ethics and the competitive advantage relationship. Accordingly, the following hypotheses are proposed:

Hypothesis 8. *Green product innovation positively mediates the impact of GSCM on CE performance.*

Hypothesis 9. *Green process innovation positively mediates the impact of GSCM on CE performance.*

Hypothesis 10. *Green management innovation positively mediates the impact of GSCM on CE performance.*

4. Methodology

4.1. Sample

This study's population included all manufacturing firms that operate in Jordan, a total of 1793 firms [81]. Given this population, a sample size of 317 was considered appropriate [82]. The manufacturing firm is the unit of analysis used in this study. Because the number of firms belonging to a single industry in Jordan is small, manufacturing firms from different industries were included. The participating firms were selected using a simple random method. This method, while prevalent in operations and supply chain management research, has some limitations. Notably, compiling the complete list of manufacturing companies can be time-consuming, and contacting the selected companies involves further time commitment, effort, and associated costs. One of the authors personally visited the selected firms to request their involvement in the research. This was carried out to increase the response rate, as most firms in Jordan have a tendency to disregard e-questionnaires or those mailed to them. One manager with sufficient knowledge regarding the study variables was contacted at each firm and asked to respond to the research questionnaire. These comprised managers of SC, operations, plants, general and executive managers, and others. The data collection process started with the visitation of each selected company by one of the researchers. Initially, contact was established with the human resource department to introduce the study's objectives. The department was briefed on the study's theme, the necessary expertise of the targeted respondents, and the topic's relevance. Notably, in smaller-sized companies where a formal SC manager role was absent, the responsibility for SC management rested with the operations managers. Human resource officers aided in identifying suitable and available respondents within each company.

They were informed about the study's purpose and procedures and assured that the gathered data would be treated as confidential and would be used only for scientific research. The data collection process lasted for two and a half months, from January to March 2022. Ultimately, the number of completed and usable returned questionnaires was 278, yielding a response rate of 87.6%. The hand delivery of the questionnaires resulted in a high response rate. The profiles of the participants and the surveyed firms are summarized in Table 1.

Table 1. Profiles of respondents and surveyed companies.

Category	Frequency	Percentage (100%)
Gender		
Male	229	82.4
Female	49	17.6
Total	278	100.0
Job Position		
Supply chain manager	109	39.2
Operations manager	82	29.5
Plant manager	38	13.7
Executive manager	30	10.8
Others	19	6.8
Total	278	100.0
Company age		
Less than 5 years	21	7.5
5–less than 10 years	39	14.1
10–less than 15 years	104	37.4
15 years and above	114	41
Total	278	100.0
Respondent's experience		
Less than 5 years	74	26.6
5–less than 10 years	89	32.1
10–less than 15 years	52	18.7
15–less than 20 years	36	12.9
20 years and above	27	9.7
Total	278	100.0
Industry Type		
Machinery and hardware	44	15.8
Electrical and electronics	41	14.8
Chemical	40	14.4
Food	40	14.4
Textiles and garments	38	13.7
Rubber and plastic	25	8.9
Pharmaceutical	18	6.5
Paper and packaging	11	3.9
Others	21	7.6
Total	278	100.0

Table 1. *Cont.*

Category	Frequency	Percentage (100%)
Number of employees		
Less than 100	103	37.1
100–less than 200	124	44.6
200–less than 300	32	11.5
300 and above	19	6.8
Total	278	100.0

4.2. Questionnaire and Measures

To reach the intended goals of this study, a survey questionnaire was prepared based on the published literature. The constructs were adopted from published studies in the English language [11,63,70,83–86]. These items were selected due to their extensive use in the extant literature and their demonstrated high levels of validity and reliability in previous studies. For instance, Chiou et al. [70] reported composite reliabilities of 0.77 for product innovation, 0.96 for process innovation, and 0.92 for management innovation. Additionally, Zeng et al. [11] found an alpha value of 0.897 for CE performance. An English version of the questionnaire was prepared first, and then the authors translated it into Arabic. Next, business administration professors with both teaching and research experience in operations and SCM were asked to review both versions of the questionnaire. They ensured the suitability of the question items for each construct and the appropriateness of the translation. Based on the feedback received, amendments and revisions were made. In addition, the questionnaire was circulated to seven managers of manufacturing firms to check the understandability and clarity of the survey items. Accordingly, additional modifications were made as needed.

The respondents were required to specify the degree of their agreement or disagreement with each of the included items based on a five-point Likert scale, with 1 indicating "strong disagreement" and 5 indicating "strong agreement." Table 2 shows the items used to measure the study constructs and the sources of each construct.

Table 2. Measurement items.

Item Number	Item Descriptions (Reference)
Eco-design [86]	
ECD1	Our firm emphasizes the design of products for reduced consumption of material/energy
ECD2	Our firm emphasizes the design of products that can be reused, recycled, and recovered
ECD3	Our firm emphasizes the design of products to reduce the use of harmful/toxic materials
ECD4	Our firm emphasizes optimization of the design process to reduce air emissions and noise
ECD5	Our firm emphasizes the optimization of the design process to reduce solid and liquid waste
Green purchasing [85]	
GP1	Our firm cooperates with suppliers to meet environmental objectives
GP2	Our firm emphasizes purchasing eco-friendly materials
GP3 *	Our firm evaluates suppliers based on specific environmental criteria
GP4	Our firm cooperates with suppliers who have environmental certifications. such as ISO 14001
GP5	Our firm has partnerships with suppliers that aim to provide environmental solutions and/or develop environmentally friendly products
Cooperation with customers [86]	
CWC1	Our firm cooperates with customers to produce eco-designs
CWC2	Our firm cooperates with customers to design cleaner production processes
CWC3	Our firm cooperates with customers for green packaging
CWC4	Our firm has an information-sharing structure with customers
CWC5 *	Our firm cooperates with customers to use less energy during product transportation

Table 2. *Cont.*

Item Number	Item Descriptions (Reference)
Internal environmental management [85]	
IEM1	Senior managers in our firm are committed to green supply chain management
IEM2	Our firm emphasizes cross-functional cooperation for environmental improvements
IEM3	Our firm emphasizes environmental compliance and auditing programs
IEM4	Our firm has pollution prevention plans
IEM5	Our firm has a system to track environmental laws and regulations
Green product innovation [70,83]	
GPRD1	Our firm uses environmentally friendly materials [70]
GPRD2	Our firm designs and uses environmentally friendly packaging for products [70]
GPRD3	Our firm uses materials that are easy to recycle, reuse, and decompose [83]
GPRD4	Our firm recovers the company's end-of-life products and recycling [70,83]
GPRD5	Our firm uses eco-labeling [70,83]
Green process innovation [70,83]	
GPRC1	Our firm has low energy consumption such as water, electricity, gas and petrol during production/use/disposal [70,83]
GPRC2	Our firm recycles, reuses, and remanufactures materials or parts [70,83]
GPRC3	Our firm uses cleaner technology to make savings and prevent pollution (such as energy, water, and waste) [70,83]
GPRC4	Our firm invests in plant and equipment, lighting, heating, and services that are tailored to the environmental evaluation [83]
Green management innovation [70,84]	
GMGT1	Our firm's management redefines operation and production processes to ensure internal efficiency [70]
GMGT2	Our firm's management redesigns and improves products and services to obtain new environmental criteria [70]
GMGT3	Our firm's management encourages and motivates employees to adopt a responsible attitude to remove waste [84]
GMGT4	Our firm's management decreases fines for environmental accidents [84]
Circular economy performance [11,63]	
CEP1	Our firm is devoted to reducing the unit product manual input [11]
CEP2	Our firm is devoted to reducing the consumption of raw materials and energy [11,63]
CEP3	Our firm initiatively enhances the energy efficiency of production equipment [11]
CEP4	Product packaging materials are used repeatedly [11]
CEP5	Equipment cleaning materials are used repeatedly [11]
CEP6	Leftover material is used repeatedly to manufacture other products [11]
CEP7	Waste produced in the manufacturing process is recycled [11,67]
CEP8	Waste products from consumers are recycled [11]
CEP9	Recycled waste and garbage are reprocessed [11,63]
CEP10	Waste and garbage are used after reprocessing to manufacture new products [11,63]

Note: *: deleted items.

5. Data Analysis and Results

5.1. Assessment of the Measurement Model

To appraise the properties of the research constructs and model, appropriate validity and reliability tests were applied. Specifically, the constructs had to fulfill the requirements of unidimensionality, convergent validity, and composite reliability (CR) [87].

To assess the unidimensionality of the research variables, confirmatory factor analysis (CFA) was run using Amos 24.0 [88]. CFA also allows for the evaluation of the overall measurement model [87]. Eight first-order variables were included in the model, and each item was linked to its respective construct. Those items that demonstrated factor loadings greater than 0.50 were kept [87]. Two items failed to meet this condition and were removed. The retained items provided support for convergent validity and supported the requirements for the unidimensionality of the first-order constructs [88]. Also, the value of average variance extracted (AVE) was calculated for first-order constructs. All of the obtained values exceeded 0.50, adding further confirmation for convergent validity [89]. The measurement model was assessed by evaluating its fit indices. The fit indices with the first-order variables showed appropriate levels and demonstrated acceptable validity (χ^2 = 739.864; df = 465; χ^2/df = 1.591; CFI = 0.958; IFI = 0.956; TLI = 0.947; RMSEA = 0.056;

and RMR = 0.042). In addition, the composite reliability of the first-order variables was computed and exceeded the threshold of 0.70 for all variables [89].

The second-order construct of GSCM was used during the hypothesis testing; therefore, additional validity and reliability tests were performed for the model with this GSCM construct. The model fit indices demonstrated satisfactory values (χ^2 = 813.576; df = 478; χ^2/df = 1.702; CFI = 0.922; IFI = 0.927; TLI = 0.924; RMSEA = 0.063; and RMR = 0.049). Regarding factor loadings, all exceeded 0.50 for the second-order construct. In addition, the AVE value was computed for the second-order construct and was greater than 0.50 (0.675). Similarly, the value of CR for this construct surpassed 0.70. Consequently, convergent validity with the second-order construct was assumed. The results of the validity and reliability tests are reported in Table 3.

Table 3. Reliability and validity of the constructs.

Construct	Item Number	Mean	Standard Deviation	Loadings CFA	Composite Reliability
Eco-design	ECD1	4.37	0.758	0.648	0.864
	ECD2			0.697	
	ECD3			0.791	
	ECD4			0.853	
	ECD5			0.741	
GP	GP1	3.78	0.738	0.767	0.821
	GP2			0.626	
	GP4			0.787	
	GP5			0.736	
CWC	CWC1	3.94	0.863	0.830	0.866
	CWC2			0.827	
	CWC3			0.745	
	CWC4			0.739	
IEM	IEM1	4.13	0.764	0.719	0.843
	IEM2			0.786	
	IEM3			0.807	
	IEM4			0.643	
	IEM5			0.636	
GSCM [a]	IEM [b]	4.05	0.641	0.813	0.890
	GP [b]			0.942	
	CWC [b]			0.867	
	ECD [b]			0.631	
GPRD	GPRD1	3.37	0.862	0.842	0.896
	GPRD2			0.768	
	GPRD3			0.753	
	GPRD4			0.816	
	GPRD5			0.794	
GPRC	GPRC1	3.78	0.696	0.786	0.839
	GPRC2			0.692	
	GPRC3			0.847	
	GPRC4			0.675	
GMGT	GMGT1	3.95	0.714	0.723	0.805
	GMGT2			0.746	
	GMGT3			0.682	
	GMGT4			0.697	

Table 3. *Cont.*

Construct	Item Number	Mean	Standard Deviation	Loadings CFA	Composite Reliability
CEP	CEP1	3.65	0.874	0.718	0.916
	CEP2			0.686	
	CEP3			0.687	
	CEP4			0.723	
	CEP5			0.743	
	CEP6			0.673	
	CEP7			0.726	
	CEP8			0.708	
	CEP9			0.745	
	CEP10			0.811	

Note: [a] second-order construct; [b] second-order indicators.

Furthermore, discriminant validity was assessed to ensure the uniqueness of the first-order constructs used in the current study. The discriminant validity assessment was carried out by obtaining the square root of each AVE value of the first-order constructs and ensuring that it exceeded all the correlations between that construct and all other constructs [89]. The discriminant validity results reported in Table 4 show that this condition was met for all the constructs, indicating that discriminant validity was not a concern in the present study.

Table 4. Assessment of discriminant validity.

Construct	AVE	1	2	3	4	5	6	7	8
1. ECD	0.562	**0.749**							
2. GP	0.535	0.523	**0.731**						
3. CWC	0.619	0.511	0.569	**0.786**					
4. IEM	0.521	0.476	0.548	0.567	**0.721**				
5. GPRD	0.632	0.716	0.467	0.423	0.472	**0.794**			
6. GPRC	0.568	0.568	0.408	0.486	0.436	0.618	**0.753**		
7. GMGT	0.508	0.437	0.482	0.539	0.586	0.673	0.742	**0.712**	
8. CEP	0.523	0.647	0.428	0.475	0.538	0.397	0.423	0.465	**0.723**

Note: The square root of AVE is on the diagonal.

5.2. Results

The PROCESS macro in SPSS (model 4) for multiple parallel mediators was carried out to test the study hypotheses [90]. It enabled the concurrent examination of direct, indirect, and total effects via the bootstrapping resampling process [91]. Based on Hayes's [90] recommendations, the number of bootstrap samples chosen was 5000, and confidence intervals (CIs) were set at a 95% level. The absence of the number zero between the two limits of the CIs, the lower limit (LL) and upper limit (UL) of each path, indicated that the alternative hypothesis was supported [92].

The direct impact of GSCM on CE performance proved to be significant and positive ($\beta = 0.422$, $p = 0.01$). Accordingly, hypothesis 1 was accepted. Furthermore, GSCM positively and significantly affected GPRD ($\beta = 0.404$, $p = 0.01$), GPRC ($\beta = 0.679$, $p = 0.01$), and GMGT ($\beta = 0.694$, $p = 0.01$). Thus, hypothesis 2, hypothesis 3, and hypothesis 4 were accepted. As for the impact of green innovation types on CE performance, the results indicated that each of GPRD ($\beta = 0.245$, $p = 0.01$), GPRC ($\beta = 0.171$, $p = 0.01$), and GMGT ($\beta = 0.189$, $p = 0.01$) positively and significantly affected CE performance, supporting hypothesis 5, hypothesis 6, and hypothesis 7.

With regard to the mediation results, GPRD significantly and positively mediated the impact of GSCM on CE performance ($\beta = 0.099$, $CI_{LL} = 0.056$, $CI_{UL} = 0.152$), which supports hypothesis 8. GPRC also proved to significantly and positively mediate the impact of GSCM on CE performance ($\beta = 0.116$, $CI_{LL} = 0.023$, $CI_{UL} = 0.215$), providing support for hypothesis 9. Lastly, GMGT likewise positively and significantly mediated the GSCM–CE performance relationship (β = 0.131, CI_{LL} = 0.040, CI_{UL} = 0.222), confirming hypothesis 10. As the direct impact of GSCM on CE performance with the inclusion of the mediators remained significant (β = 0.422, p = 0.01), this indicated that the three green innovation types partially mediated the GSCM–CE performance relationship [93]. The total impact of GSCM on CE performance was the summation of both the direct impact and the indirect impact. Consequently, the total impact equaled 0.768 (i.e., 0.422 + 0.099 + 0.116 + 0.131 = 0.768). A summary of the results is presented in Table 5.

Table 5. Summary of results.

Hypothesis	Path	Mediated Model	Bias Corrected Bootstrap 95% Confidence Interval		Result
			Lower	Upper	
H1	GSCM → CEP	0.422 **	0.294	0.488	Supported
H2	GSCM → GPRD	0.404 **	0.258	0.468	Supported
H3	GSCM → GPRC	0.679 **	0.525	0.694	Supported
H4	GSCM → GMGT	0.694 **	0.614	0.802	Supported
H5	GPRD → CEP	0.245 **	0.173	0.331	Supported
H6	GPRC → CEP	0.171 **	0.062	0.290	Supported
H7	GMGT → CEP	0.189 **	0.070	0.274	Supported
H8	GSCM → GPRD → CEP	0.099 (indirect effect)	0.056	0.152	Supported
H9	GSCM → GPRC → CEP	0.116 (indirect effect)	0.023	0.215	Supported
H10	GSCM → GMGT → CEP	0.131 (indirect effect)	0.040	0.222	Supported

Note: ** $p < 0.01$.

6. Discussion, Conclusions, and Implications

6.1. Discussion

The findings showed that GSCM positively and directly impacted CE performance. The results are generally consistent with prior studies [5,11,94]. However, some differences exist between our study and prior studies. For instance, Zeng et al. [11] found that supply chain relationship management (SCRM) and sustainable supply chain design (SSCD) positively affected CE capability in eco-industrial parks in China. Our study differs from their study by investigating the impact of GSCM on CE performance in a developing country. In addition, Kazancoglu et al. [5] provided a conceptual framework concerning the impact of GSCM on the CE, while our study provided empirical evidence regarding this relationship. Our result signifies the essential role of GSCM practices in boosting manufacturing firms' ability to raise their environmental results and efficiency by optimizing the use of materials and energy sources. The findings also highlight an important issue regarding CE performance. Internal environmental activities and efforts are not sufficient to attain high levels of CE performance. Rather, green SC coordination with suppliers to obtain environmentally friendly materials and components, along with the involvement and collaboration with customers to apply appropriate product return policies, recycling activities, and reuse procedures, are expected to lead to superior CE performance. When manufacturers adopt green practices, they meet the principles related to reducing, reusing, and recycling products, resulting in reduced consumption of materials and energy and decreased pollution levels in the closed-loop cycle, leading to higher CE performance.

The results further demonstrated that GSCM positively affected all three types of green innovation. These results are in line with prior studies [70–73]. Our study differs from previous studies in that we examined the impact of GSCM on each individual green innovation type rather than on an overall construct of green innovation that encompasses different innovation types. Some other differences exist between our study and previous studies. For example, Chen et al. [71] conducted a literature review, while our study provided empirical evidence concerning this relationship. Also, Abu Seman et al. [73] examined the impact of GSCM on an overall construct of green innovation in Malaysia, while our study investigated the impact of GSCM on individual dimensions (i.e., product, process, and managerial) of green innovation. Furthermore, Chiou et al. [70] demonstrated that greening suppliers positively affected product, process, and managerial innovations in Taiwan. Our study differs by investigating the impact of GSCM on the three types of green innovation. Interestingly, the results revealed that the impact of GSCM on green management and process innovation was noticeably higher than product innovation. This may be attributed to the fact that GPRD is concerned with improvements in product design and quality with respect to environmental issues that often require new technologies and significant investment. GRPC is concerned with improvements in operations, sourcing, and logistics processes to reduce resource consumption and emissions. Thus, GPRD can be more costly than GPRC and GMGT. Furthermore, GPRC and GMGT enable companies to implement significant improvements related to cost savings, environmental efficiency, green reputation, and green image [95].

The three types of green innovation proved to affect CE performance positively and significantly. While our findings are generally in line with some prior studies [13,14,76], certain distinctions are evident. De Jesus et al. [13] conducted an analytical literature review, whereas our study provides empirical evidence regarding the impact of green innovations on CE performance. Additionally, Maldonado-Guzmán et al. [14] found a positive influence of the three innovation types on the CE in the automotive and auto parts industry in Mexico. Notably, our study differs as it was conducted among SMEs in a developing context, while their study focused on large companies. Furthermore, Bag et al. [76] found a positive impact of an overall eco-innovation construct on CE capability in South Africa, whereas our study explored the of individual green innovation types on CE performance. Green innovations are considered restorative and are intended to take remedial actions against damage to the environment. Therefore, green innovations play an essential role in enhancing CE performance and attaining the associated closed-loop cycle [76]. The findings revealed that the highest contributing innovation types to CE performance were GPRD, GMGT, and GPRC, respectively. While GPRD was the least innovation type affected by GSCM, it had the highest impact on CE performance. This could be because GPRD innovation is costly and may require specialized technologies and advanced knowledge. Our results suggest that once companies can successfully adopt this innovation type, it is expected to have the highest impact on CE performance.

Finally, the three green innovation types positively mediated the GSCM–CE performance relationship. These results indicate that green innovations are effective strategies for enhancing the CE performance of manufacturing companies. Our findings suggest that GSCM is one of the main drivers of green innovation and CE performance. By promoting green innovations, GSCM is expected to further enhance CE performance via these innovations. Although these environmental concepts are still in their infancy in Jordan, they may reflect environmental awareness among manufacturing companies. Companies that can direct their GSCM efforts to promote green innovations are anticipated to attain high levels of CE performance. To the best of our knowledge, this is the first study to provide empirical evidence regarding the mediating effects of three types of green innovations on GSCM–CE performance. Nonetheless, our results are partially in line with Abu Seman et al. [73], who demonstrated the mediating impact of green innovation (in terms of an overall construct) on GSCM and the environmental performance relationship in Malaysia.

6.2. Conclusions

The present study examined GSCM's impact on green innovations and CE performance in Jordanian manufacturing companies. The impact of green innovations on CE performance was also explored. In addition, the indirect impact of GSCM on CE performance via green innovations was investigated.

The study showed that GSCM is an important driver of green products, processes, and management innovations. Additionally, the results showed that the impact of GSCM on CE performance was high. Moreover, the study highlighted the important role of the three types of green innovation in boosting CE performance levels. Furthermore, the findings showed that the three types of green innovations (product, process, and management) positively mediated the GSCM–CE performance relationship. The present study offers a better understanding of GSCM's impact on green innovations and CE performance and provides new insights into the implications of these vital environmental concepts.

6.3. Theoretical Contribution

The current study offers some theoretical contributions. First, it adds to the existing literature by providing empirical evidence concerning the influence of GSCM on green innovation and CE performance. Additionally, the present study extends prior work by examining the impact of green innovations on CE performance and exploring the mediation effects of green innovations on the GSCM–CE performance relationship. Second, this is one of the first studies to examine the impact of GSCM on three different types of green innovation: product, process, and management innovations. Similarly, this is one of the first studies to provide empirical verification regarding the impact of each individual green innovation type on CE performance. Moreover, to the best of our knowledge, this study is the first to investigate the mediating impacts of the three green innovation types on GSCM–CE performance. Third, an additional contribution of the current study to the literature is that it is among the first to investigate the proposed model in a developing country. The findings will enrich the existing body of knowledge and provide new insights for researchers in various geographical regions.

6.4. Managerial Implications

This study offers some suggestions and implications for decision makers in the manufacturing industry. Managers need to pay particular attention to the crucial role of GSCM in promoting green innovations and boosting CE performance. Managers who can adopt appropriate GSCM practices and direct them to generate green innovations can comply with environmental regulation requirements and achieve superior levels of CE performance. In addition, while several manufacturers often focus on achieving green technological innovation (green product innovation and green process innovation), the present study highlights the essential role of non-technological green innovation (green management innovation). The expected role of management innovation is not restricted to enhancing CE performance, but it has been argued in the literature that management innovation facilitates and supports the adoption of both green product and process innovations [57]. While the implementation of the proposed environmental strategies may appear costly and difficult for managers in developing countries, the implementation of these environmental strategies assures the sustainability of their businesses and compliance with various environmental regulations locally and internationally. This will help them to export their products to different countries, especially those which impose strict environmental requirements on imported products. The high initial cost associated with the implementation of environmental strategies can be recovered over the long term by sustaining the business, improving the company's reputation, and increasing the volume of exported products.

6.5. Limitations and Future Research Directions

The present study has limitations that could be considered in future research. First, the study examined the impact of an overall GSCM construct on green innovation and CE performance. Although the study provided useful findings and implications, it did not examine the contribution of individual GSCM practices. Future studies are needed to explore the impact of individual GSCM practices on green innovations and CE performance to provide further insights and implications. Second, the sample of this study comprised companies from various industries because the number of firms belonging to any one type in Jordan is small. However, the implementation level of environmental strategies may vary across industries. Also, several distinctions exist among different industries, including technology type, SC design and structure, product characteristics, and environmental impact. Future studies can be carried out in a specific industry to obtain more in-depth information regarding the proposed relationships. Third, from each participating company, only one manager was invited to respond to the questionnaire. While this approach is widely used by researchers, it may reduce the generalizability of the findings. Future studies might use a multiple-informant procedure to increase the generalizability of the findings. Fourth, given the exploratory nature of this study, the indicators used to assess CE performance primarily capture initial tendencies and efforts toward implementing CE principles rather than directly providing a comprehensive assessment of CE performance over time. Future studies are encouraged to refine and apply more comprehensive indicator sets to assess specific CE performance factors over time, thereby solidifying the performance construct of the CE. In addition, future studies recommended examining the reversed causal relationships by investigating the impact of the CE on GSCM mediated by green innovations. Exploring how CE practices drive green innovations, and GSCM could offer profound insights into tailored sustainability strategies within unique industrial contexts.

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