“Green supply chain practices and competitive advantage: The roles of integration and environmental uncertainty”

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GREEN SUPPLY CHAIN PRACTICES AND COMPETITIVE ADVANTAGE: THE ROLES OF INTEGRATION AND ENVIRONMENTAL UNCERTAINTY

Abstract

In highly dynamic markets with regulatory, market, and technological pressures, especially in emerging economies, manufacturing companies are increasingly striving to become environmentally sustainable, mitigate environmental liabilities, and enhance their competitive advantage. This study investigates the relationship between green supply chain practices and competitive advantage in Jordanian manufacturing companies through the lens of supply chain integration as a mediator and environmental uncertainty as a moderator. From March to June 2025, a quantitative, cross-sectional survey was conducted among managers whose direct responsibilities include supply chain management, procurement, operations, environmental management, and strategic decision-making. After data screening, 254 responses eligible for analysis were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 4. Green supply chain practice was found to have a positive relationship with supply chain integration ($\beta = 0.676$, $p < 0.001$) and competitive advantage ($\beta = 0.298$, $p = 0.012$) among respondents. Supply chain integration was also positively associated with competitive advantage ($\beta = 0.527$, $p < 0.001$), and the estimated indirect effect of SC integration was statistically significant ($\beta = 0.356$, $p < 0.001$). The interaction between green supply chain practices and environmental uncertainty was positive and statistically significant in predicting competitive advantage ($\beta = 0.172$, $p = 0.021$), indicating that it might be stronger in a more uncertain environment. Overall, the results suggest that supply chain integration could be a strategy to achieve competitive results from the environment. But the findings should be viewed as statistical relationships, not causal relationships, given a cross-sectional, self-reported, single-informant, non-random sample in one national manufacturing context.

Keywords sustainability, integration, competitiveness, uncertainty, manufacturing, Jordan

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INTRODUCTION

As manufacturing activities and value chains are closely linked to energy and resource use, emissions, waste and other environmental impacts, manufacturing companies face growing pressure to improve environmental sustainability. An increasing number of regulatory obligations, stakeholder expectations and market demands for environmental business responsibility have thus spurred companies to expand environmental management to their suppliers, customers, logistics service providers and other supply chain partners, Green Supply Chain (GSC) practices have gained significance in integrating environmental factors in purchasing, production, product and process design, logistics and interorganizational relationships (Ahmed Mustafi et al., 2025; Al Amin et al., 2025; Shebeshe & Sharma, 2026; Singh et al., 2025; Van et al., 2025).

This issue is relevant with particular complexity to the Jordanian manufacturing companies. Jordan's manufacturing industry has diverse sectors, such as pharmaceuticals, food and beverages, textiles

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and garment, chemicals and fertilisers, plastics, and engineering industries—all vary in their resource intensity, environmental exposure, supply chain complexity, and reliance on domestic and international markets. At a strategic level, strong linkages between manufacturers, suppliers, customers, and logistics service providers are vital to Jordan's Economic Modernisation Vision, which focuses on boosting industrial productivity, value-chain development, innovation, exports, and international competitiveness (Government of Jordan, 2022). The national regulatory framework also reaffirms environmental considerations, such as Environmental Protection Law No. 6 of 2017 and Environmental Classification and Licensing Regulation No. 69 of 2020 on conditions of environmental licensing, impact assessment, waste management, hazardous materials, industrial emissions and environmental inspection (Ministry of Environment, 2017, 2020).

Although the strategic relevance of environmentally responsible value chains is increasing, an important scientific problem remains concerning the conditions under which GSC practices result in competitive advantage. Environmental programs can be a good opportunity to increase resource efficiency, coordination, differentiation, responsiveness and reputation, but can also involve significant financial, technological and managerial investments. Therefore, it is not sufficient to assure better competitive results by implementing only GSC practices. This issue is especially relevant for nascent manufacturing firms that can be constrained by scarce resources, regulatory pressures, evolving market expectations, and environmental uncertainty. In this regard, there is a need to better understand the organizational and environmental factors that influence the competitiveness of green supply chain practices in manufacturing companies in Jordan.

1. LITERATURE REVIEW AND HYPOTHESES

The theoretical base of this study is mainly gained from the Natural Resource-Based View (NRBV) and contingency-based reasoning. The NRBV provides an example of how an environment can play a useful role in the generation of competitive advantage when it is valuable, it forms part of the company's processes, and it is difficult for competitors to replicate (Hart, 1995). But environmental activities can lose their value competitively if they do not on their own. Their work can rely on ancillary organizational capabilities that support the coordination of activities, sharing of information, and the initiation of environmental efforts within and between organizational and functional units. In this paper, supply chain integration is viewed as a supporting capability to assist businesses in converting green supply chain practices into competitive advantage. Contingency-based reasoning is another view that can be added to this argument: Organizational practices may be more or less effective depending on the external conditions in which firms operate (Wilden et al., 2013). To this end, environmental uncertainty is considered to be one of the contextual factors that could affect the relationship between green supply chain practices and competitive advantage.

An environmentally oriented managerial and operational activity, which is established throughout procurement, production, distribution, logistics, cooperation with supply chain partners, and end-of-life processes, is considered green supply chain practices. Typical examples of these practices are green purchasing, eco-design, cleaner production, waste minimization, recycling, cooperation with the environment, and reverse logistics (Javed et al., 2025; Santos et al., 2025; Mustafi et al., 2026). As companies strive to minimize environmental impact, optimize operational efficiency, and meet stakeholders' needs, their significance has grown. Green Supply Chain practices are now therefore being seen not just as compliance approaches, but as strategic practices that can have a positive impact on sustainability, operational enhancement, and long-term competitiveness (Nawafleh et al., 2026).

From the perspective of the NRBV, green supply chain practices may become strategically valuable once they are routinized and facilitated with complementary capabilities within the organization. These practices can contribute to waste reduction, efficient resource use, enhancing environmental legitimacy, and more effectively meeting stakeholder expectations (Hart, 1995; Kurrahman et al., 2025; Yan et al., 2026). But the competitive worth

of environmental practices is contingent on the extent to which firms do this. Green actions that are not integrated into purchasing, production, logistics, and partner relationships are likely to have limited impact on the organization or the market.

The results of the studies of the relationship between GSC and competitive advantage have been inconsistent. Environmentally oriented activities can boost cost-efficiency, differentiation, responsiveness, innovation, reputation, and market positioning through a reduction in inefficiencies and enhance relationships with environmentally conscious customers and supply chain partners (Ahmed Mustafi et al., 2025; Al Amin et al., 2025; Shebeshe & Sharma, 2026; Singh et al., 2025). For instance, with green purchasing, it becomes possible to limit exposure to non-environmentally compliant suppliers, and with eco-design and waste-reduction projects to increase product value and efficiency in operations. These benefits can include both internal performance gains and more robust market positioning, which can enhance competitive advantage.

However, implementing green supply chain practices may also incur significant implementation costs, technology investments, management involvement, employee training, information sharing, and supplier engagement. However, a lack of resources and organizational capabilities within a firm can lead to higher costs without any significant competitive advantages, especially in the short term (Schilling & Seuring, 2024; Febrianto & Rufaidah, 2026). The relationship between GSCP and competitive advantage is not a foregone conclusion, as evidenced by these conflicting conclusions. Rather, it may rely on the organizational arrangements for enacting ecological practices and on the context of a firm.

Green supply chain (GSC) practices might be integrated in the supply chain to be an important mechanism that translates to competitive outcomes. Supply chain integration is related to how well a firm integrates the various processes and the degree to which it shares information with suppliers and customers, plans together, aligns its operations, and makes coordinated decisions. It is generally considered to include internal integration, supplier integration, and customer integration. Internal integration takes place between functions and departments, whilst supplier and customer integration take place between external supply chain partners.

Programs that involve the green supply chain often involve a great deal of collaboration between functions and organizations. For the sake of green purchasing, environmental criteria need to be communicated to suppliers, and their environmental performance needs to be assessed. Eco-design can involve all purchasing, production, product development, marketing, and outside suppliers. Therefore, information sharing and joint activities between manufacturers, suppliers, customers, and logistics providers are frequently necessary for waste reduction, recycling, and environmental monitoring, as well as product reverse logistics (Wu et al., 2025; Do et al., 2026). Thus, green supply chain practices can lead companies to prefer more integrated supply chain arrangements, rather than fragmented environmental practices.

The quality of the interaction between firms and supply chain partners can be improved through environmental standards, joint monitoring systems, collaborative problem-solving, and shared sustainability goals. Green implementation for firms, therefore, can possibly lead to better coordination within the firms and building a relationship with their suppliers and customers to cater for environmental requirements and to align internal operations. In recent studies, the relationship between supply chain initiatives and the environment has been closely linked with integration, sharing of knowledge, coordination, and responsiveness (Javed et al., 2025; Javed et al., 2026; Li et al., 2026). Based on this thinking, it can be assumed that green supply chain practices have the potential to positively affect the development of supply chain integration.

Integration of the supply chain can also add to competitive advantage. Integrated supply chains can enhance the flow of information, minimize duplication of effort, synchronize decision-making, and provide a more responsive approach to customer and market needs. Purchasing integration, production integration, logistics integration, marketing integration, and environmental integration can all be achieved within the company,

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and supplier integration can be carried out to enhance the quality and reliability of material supply or to jointly solve problems. Customer integration can improve demand visibility, responsiveness, and service performance. These advantages can contribute to cost reduction, flexibility, delivery, innovation, and differentiation – all significant aspects of competitive advantage (Elnadi et al., 2026; Rahman et al., 2026; Shakeel & Siddiqui, 2026; Sohu et al., 2026).

The mediation of supply chain integration offers a more in-depth understanding of the relationship between green supply chain practices and competitive advantage. Green practices can lead to direct competitive gains via resource savings, eco-image, and differentiation. They can also generate indirect benefits by promoting the sharing of information and coordination, joint planning, and collaboration throughout the supply chain. Take green purchasing as an example: if environmental criteria are communicated to suppliers well and taken into account in the purchasing process, the results are better. In the same way, differentiation can be enhanced by eco-design if product development, production, marketing, and supplier activities all have a say in it. In this regard, supply chain integration could be a mechanism that supports business to convert environmental initiatives into increased efficiency, responsiveness, differentiation and market positioning. This is aligned with the NRBV, implying that the value of environmentally oriented resources, in combination with complementary organizational capabilities, is enhanced (Hart, 1995; Agyabeng-Mensah et al., 2021; Javed et al., 2026).

There may also be a moderating effect between green supply chain practices and competitive advantage in the presence of environmental uncertainty. Increased environmental uncertainty is the lack of ability by firms to predict fluctuations in the regulatory environment, market conditions, technological environment, customer expectations, and competitive intensity (Wilden et al., 2013). In uncertain circumstances, companies might find it more difficult to plan their activities, allocate resources, and match internal resources with external demands. In this context, environmentally-focused behaviors can become more strategically relevant as they can contribute to increased effectiveness in the use of resources, adaptability, creating trust among stakeholders, and responsiveness of organizations (Agazu et al., 2026).

Contingency-based reasoning argues that the effectiveness of a strategic practice is contingent on the external environment of its practice. During relatively stable conditions, firms may not be under significant pressure to do more on the environmental dimension to differentiate themselves or significantly change their source of supply activities. However, in more uncertain environments, green supply chain practices might assist a company to react to regulatory changes, changing customer demands, technological innovation, and competition. Through green purchasing and environmental cooperation, risks in relationships with suppliers and customers may be reduced, and waste reduction and resource-efficiency measures may minimize effects on cost and supply volatility. Past studies also indicate that some of the organizational and environmental capabilities can become more strategically important during dynamic and unpredictable situations (Almheiri et al., 2025; Magdy & Elmakkawy, 2025; Febrianto & Rufaidah, 2026).

However, even in a highly uncertain environment, green supply chain practices do not necessarily ensure a better competitive result. Firms need the organizational and supply chain capacity to detect environmental changes and react accordingly. In this study, however, environmental uncertainty is not considered as an antecedent of the relationship between GSPs and CA but only as an environmental context that may shape the relationship between GSPs and CA.

In general, significant relationships between green supply chain practices, supply chain integration, sustainability, and organizational performance have been documented by prior studies (Nyamah et al., 2026). But most of the current literature is limited to the immediate effects of green activities and does not provide a clear definition of the organizational mechanism by which such activities are translated into competitive benefits. Supply Chain Integration (SCI) has been studied as an isolated determinant of performance and not as a complementary capability that can act as a conduit through which the benefits of adopting GSC can

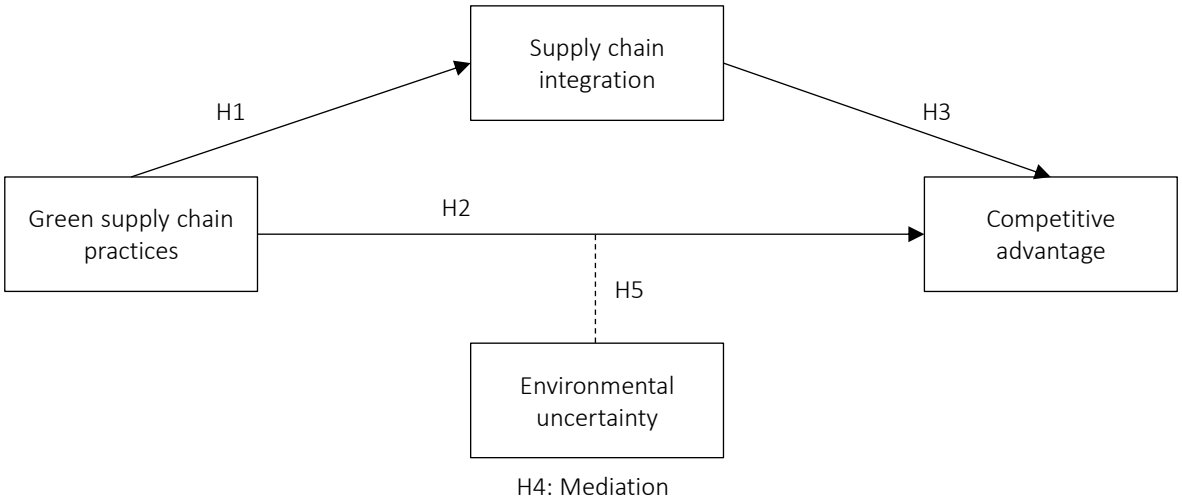

Figure 1. Research model

be transferred. As with the other, environmental uncertainty has often been researched separately from the link between environmental actions and competitive advantage. As a result, there is also a lack of interest in studying the simultaneous moderating and mediating relationship between green supply chain practices and competitive advantage. A joint examination of these relationships offers a more comprehensive description of how and which external conditions might be related to competitive results arising from green supply chain practices.

The main objective of this study is to examine the impact of GSP on competitive advantage in Jordanian manufacturing companies by examining the role played by SC integration as a mediator and the role of environmental uncertainty as a moderator.

Study hypotheses are as follows:

H1: Green supply chain practices have a positive effect on supply chain integration.

H2: Green supply chain practices have a positive effect on competitive advantage.

H3: Supply chain integration has a positive effect on competitive advantage.

H4: Supply chain integration mediates the relationship between green supply chain practices and competitive advantage.

H5: Environmental uncertainty positively moderates the relationship between green supply chain practices and competitive advantage such that the relationship is stronger under higher levels of uncertainty.

Based on the Natural Resource-Based View (NRBV) and contingency-based thinking, this paper offers a conceptual model that connects green supply chain practices, supply chain integration, environmental uncertainty, and competitive advantage. Green supply chain practices have been understood as environmentally inclined strategic resources that have an increased capacity for coordination, efficiency, and differentiation of the supply chain. However, according to the NRBV, even when these resources are supported by other complementary organizational mechanisms, they provide sustained competitive advantage.

In this context, supply chain integration is established as an important organizational resource that enables coordination, exchange of information, and alignment between supply chain partners. Proposed as a mediating mechanism, green supply chain practices are suggested to be converted into competitive advantage. Companies that embrace environmentally responsible practices are likely to intensify the process of integration, which consequently boosts cost efficiency, responsiveness, and positioning.

Furthermore, environmental uncertainty is also included in the contextual variables that moderate

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the relationship between green supply chain practices and competitive advantage. In conditions of high uncertainty, the benefits of initiatives that focus on the environment in the supply chain to firms can be stronger since differentiation based on sustainability and operational efficiency can gain stronger strategic importance.

Therefore, the study's conceptual model is presented in Figure 1.

2. METHODS

The design of the study was quantitative, which was used to explore relationships between green practices, integration in the supply chain, environmental uncertainty, and competitive advantage in Jordanian manufacturing firms. The study took place in Jordan from March to June 2025. The rationale for choosing Jordanian manufacturing firms is based on the fact that they are subjected to the context of an emerging economy, where environmental pressures, regulatory expectations, resource limitations, and the need to enhance competitiveness are growing. The context of this study is suitable for the purpose of investigating green supply chain practices, given that manufacturing activities are linked to resource consumption, waste generation, supplier coordination, and environmental compliance activities.

This study was carried out in five steps. The first study is the construction of study that is carried out based on the proposed research model. The independent variable was green supply chain practices, the mediating variable was supply chain integration, the moderating variable was environmental uncertainty, and the dependent variable was competitive advantage. Second, a structured questionnaire was created based on previously validated measurement scales. Thirdly, managers from the manufacturing sector of Jordanian companies were selected to answer the questionnaire. Fourth, only questionnaires that were complete were accepted. Finally, the valid responses were subjected to analysis using the Partial Least Squares Structural Equation Modeling (PLS-SEM) by SmartPLS 4.

The primary data were obtained by conducting a structured questionnaire survey among managers engaged in supply chain management, procurement, operations, environmental management, and executive sectors. They were chosen because they are directly engaged in decisions regarding the supply chain, environmental practices, operational coordination, and competitive strategy. Thus, they were determined to be suitable informants for the constructs involved in this study.

A total of 320 questionnaires were sent to the eligible respondents in Jordanian manufacturing companies. These questionnaires were returned as 268. Responses were screened, after which questionnaires that were not completed were discarded, leaving 254 valid questionnaires for analysis. The 254 responses that were usable for this study are the primary empirical data. The survey was conducted from March to June 2025 in manufacturing companies in Jordan.

Table 1. Survey procedure and primary data

Item	Description
Study context	Jordanian manufacturing firms
Country	Jordan
Survey period	March–June 2025
Target respondents	Managers in supply chain, procurement, operations, environmental management, and executive positions
Reason for selecting respondents	Direct involvement in supply chain decisions, environmental practices, operational coordination, and competitive strategy
Data collection method	Structured questionnaire survey
Distributed questionnaires	320
Returned questionnaires	268
Valid questionnaires used for analysis	254
Analysis software	SmartPLS 4
Main analysis method	Partial Least Squares Structural Equation Modeling

The questionnaire was structured to ensure content validity and conformity with previous studies by using previously validated measurement scales. The items were chosen because their constructs were directly associated with the constructs of the research model proposed: green supply chain practices, integration of the supply chain, environmental uncertainty, and competitive advantage. These constructs were included in the questionnaire as the study focuses specifically on explaining how environmentally oriented supply chain practices

create competitive advantage through supply chain integration under conditions of environmental uncertainty (Porter, 1985).

Supply chain integration was treated as an overall perceived integration measure which included three items corresponding to the three domains of integration: internal integration, supplier integration, and customer integration. While SC integration is a construct that may be modeled as a multidimensional construct, for the purpose of the current study, it was modeled as a singular construct given the focus of the study was on the overall mediating effect between GSP and competitive advantage. The results should therefore be viewed as overall supply chain integration and not as an effect on internal, supplier, and customer integration.

The measurement of green supply chain practices was based on the items adapted from Abdellatif and Graham (2019) and Rashid et al. (2025). The following items addressed green purchasing, ecodesign, environmental cooperation, and waste reduction. The items adapted from Duong and Ha (2021). were used to measure the level of integration in the supply chain, including the integration within the enterprise, supplier integration, and customer integration. Items that included regulatory volatility, market volatility, technological change, and competitive pressure were used to assess environmental uncertainty. The competitive advantage was determined by means of the items taken from Rashid et al. (2025), which include Cost efficiency, Differentiation, Responsiveness, and Market positioning.

The responses were based on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) for all items. The decision to use this scale was made because it can be used to measure managers' perceptions and is used in management and supply chain research. In order to increase transparency of the measurement items, the questionnaire used in this study is attached in Appendix A.

Human subjects were used in the study using a structured questionnaire survey. All participants volunteered to take part and were told the aim of the study prior to filling the questionnaire out. All participants gave informed consent. Participants were also told that their refusal to participate, or their withdrawal during the study, would have no adverse effects.

No personally identifying information was gathered for anonymity and confidentiality. The questionnaire did not ask for names, private identification numbers, personal contact information, or personal information. The answers were used only for academic research and processed in a total summary. To ensure impartiality, the questionnaire was presented in the same format to all respondents, and identical data screening and statistical analysis procedures were used with all valid responses. Sampling procedure and profile of respondents. The study used a purposive sampling technique and targeted managers with direct knowledge about the practices in supply chain, environmental initiatives, operational coordination, and competitive strategy. Respondents who could be eligible were managers or officers in charge of supply chain management, procurement, production, logistics, environmental management or executive management in Jordanian manufacturing companies. Only respondents who had enough decision-making and/or operating coordination authority related to the supply chain were included. Returns where there was an incomplete questionnaire, or there was a significant amount of missing information, were not included in the analysis. The process yielded 254 valid responses that were used as the sample for the PLS-SEM analysis. The manufacturing firm was the unit of analysis. Only one managerial respondent from each of the participating companies was included to ensure independence of the observations. This means that the 254 valid responses were from 254 different manufacturing firms, with no firm providing more than one questionnaire. The selected respondent served as a key informant, as they had direct involvement in the supply chain, procurement, operations, environmental management, or strategic decision-making.

There was no formal ethical approval as the data were collected from anonymous questionnaires and the population consisted of adult professional respondents, and no sensitive personal data was collected. However, the study adhered to principles of institutional ethics – voluntary participation, informed consent, anonymity, confidentiality, and responsible handling of data.

The data gathered for this study are newly collected and original data. The same survey results have

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not been used as the empirical basis of any other publication. The article's analyses are based on 254 valid responses received during the survey period.

Data were analyzed using Partial Least Squares Structural Equation Modeling with SmartPLS 4 software. This approach was chosen since it is suitable for testing complex models containing direct, mediating, and moderating variables. Additionally, PLS-SEM can be used for predictive research designs and in situations involving relationships among multiple latent constructs (Hair et al., 2016).

The analysis was done in two phases. The measurement model was tested in the first stage through outer loadings, Cronbach's alpha, composite reliability, AVE, the Fornell-Larcker criterion, and variance inflation factor (VIF) values. The following tests were applied to evaluate the reliability of the indicators, internal consistency, convergent validity, discriminant validity, and collinearity.

The second stage involved testing the structural model to explore the hypotheses proposed. The direct effect of green supply chain practices on supply chain integration and competitive advantage, as well as the direct effect of supply chain integration on competitive advantage, were studied. Besides, the mediating role of supply chain integration was also tested, and the moderating role of environmental uncertainty was also tested. The statistical significance of the path coefficients, mediation effect, and moderation effect was evaluated using the bootstrapping method with 5,000 resamples. To test the moderating role of environ-

Table 2. Profile of respondents and the 254 participating firms

Characteristic	Category	Frequency	Percentage
Industry sector	Food and beverages	52	20.5%
	Pharmaceuticals	38	15.0%
	Textiles and garments	44	17.3%
	Chemicals and plastics	47	18.5%
	Engineering and metal industries	39	15.4%
	Other manufacturing industries	34	13.4%
Firm size	Small	61	24.0%
	Medium	119	46.9%
	Large	74	29.1%
Firm age	Less than 5 years	32	12.6%
	5–10 years	64	25.2%
	11–20 years	87	34.3%
	More than 20 years	71	28.0%
Ownership structure	Local ownership	184	72.4%
	Foreign ownership	28	11.0%
	Joint ownership	42	16.5%
Export orientation	Exporting firm	151	59.4%
	Non-exporting firm	103	40.6%
Respondent job title	Supply chain manager/officer	58	22.8%
	Procurement manager/officer	47	18.5%
	Operations/production manager	66	26.0%
	Environmental/quality manager	39	15.4%
	Executive/general manager	44	17.3%
Professional experience	Less than 5 years	41	16.1%
	5–10 years	78	30.7%
	11–15 years	69	27.2%
	More than 15 years	66	26.0%
Department	Supply chain/logistics	62	24.4%
	Procurement	46	18.1%
	Operations/production	71	28.0%
	Environmental/quality management	35	13.8%
	Senior management	40	15.7%

Note: Percentages are based on the final valid sample of 254 respondents.

mental uncertainty, an interaction term between green supply chain practices and environmental uncertainty was created in SmartPLS 4. The indicators for the predictor construct and the moderator construct were standardized as a means of improving the interpretability of the interaction construct. The indicators of the predictor and moderator constructs were standardized to eliminate the need for nonessential multicollinearity when constructing the interaction. The two-stage method was used to estimate the interaction effect. Bootstrapping was performed with 5,000 resamples; two-tailed testing and 95% bias-corrected confidence intervals were used to assess statistical significance. Simple slope analysis was used to further explore the nature of the significant interaction at low, mean, and high levels of environmental uncertainty (one standard deviation below the mean, mean, and one standard deviation above the mean, respectively). A moderation plot was also created to depict the relationship between the use of green supply chain practices and competitive advantage at different levels of environmental uncertainty. The criteria for the evaluation of model explanatory power were R^2 and, for predictive relevance, Q^2.

Also, to better understand the empirical context, information on the respondents and participating organizations' profiles is provided. Key characteristics related to industry sector, firm size, firm age, ownership structure, export orientation, respondent job title, professional experience, and department are included in the profile. These characteristics are important due to the nature of the study on Jordanian manufacturing firms, where the level of practices in GSC, SC integration, EC, and the level of competitive advantage could be different based on the organizational and managerial characteristics. The demographic and organizational profile of the final sample is shown in Table 2.

The sample includes food and beverages, pharmaceuticals, textiles and garments, chemicals and plastics, engineering and metal industries, and other manufacturing activities as indicated in Table 2. The participating companies also have diverse characteristics in their size, export orientation, age, and ownership structure. Respondents also hold management and senior officer positions in supply chain, procurement, operations, environmental and quality management, and senior management. This profile contributes to the suitability of the sample, as respondents were in a position to make informed judgements about the green supply chain practices, supply chain integration, environmental uncertainty, and competitive advantage in Jordanian manufacturing firms.

3. RESULTS

This section presents the results of the empirical analysis of 254 valid responses from managers of manufacturing companies in Jordan. The results are broken down into four sections. Descriptive statistics, indicator loadings, and collinearity results are presented first. Secondly, the reliability and validity of the measurement model are reported. Thirdly, the results of the structural model are made available. Lastly, the findings for the hypothesis testing, mediation, and moderation analyses and model predictive powers are presented. Further diagnostic tests were carried out to examine any concerns about consistency in the empirical findings. The statistics of collinearity were tested using VIF values, and all of the values were below the recommended value, indicating that multicollinearity was not a major problem. Secondly, common method bias was examined, as the data were gathered from one survey instrument. The results did not show any critical common method bias problem. Third, discriminant validity was also tested using the Fornell–Larcker criterion with the HTMT criterion. These additional checks give further confidence in the results of the measurement and structural models.

The descriptive statistics revealed that the mean scores of the studied items varied between 3.55 and 3.81, which means that the respondents somewhat agreed with the items of the questionnaire. The standard deviations were between 0.96 and 1.12, indicating acceptable variations between the responses.

The loadings of the indicators were above the recommended level of 0.70, varying from 0.804 to 0.878. This means that each item is an appropriate representation of the constructs. The variance inflation factor values were smaller than 5, the generally accepted threshold. Thus, no serious multicollinearity issues were found, as Table 3 shows.

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Table 3. Descriptive statistics, factor loadings, and collinearity

Construct	Items	Mean	Std. Dev.	Loading	VIF
Green supply chain practices	GSC1	3.74	0.98	0.846	2.41
	GSC2	3.68	1.02	0.872	2.76
	GSC3	3.71	1.01	0.833	2.63
	GSC4	3.65	1.05	0.811	2.18
Supply chain integration	SCI1	3.59	1.07	0.854	2.94
	SCI2	3.62	1.04	0.878	3.12
	SCI3	3.55	1.09	0.829	2.71
Environmental uncertainty	EU1	3.81	0.96	0.821	1.87
	EU2	3.76	1.03	0.847	2.03
	EU3	3.79	0.99	0.804	1.42
Competitive advantage	CA1	3.66	1.08	0.864	2.88
	CA2	3.58	1.12	0.837	2.45
	CA3	3.61	1.06	0.812	2.36

Each and every construct had strong internal consistency reliability. Cronbach's alpha and composite reliability indices were above 0.70. The Average Variance Extracted (AVE) for each construct exceeded the recommended threshold of 0.50, thereby supporting convergent validity (Fornell & Larcker, 1981).

Discriminant validity was measured on the basis of the Fornell–Larcker criterion. Discriminant validity was established by the square root of the Average Variance Extracted (AVE) of each of the constructs being greater than the inter-construct correlations (Sarstedt et al., 2021).

The structural paths were resampled using bootstrapping to test the significance of 5000 resamples. The green supply chain practices also had a great impact on supply chain integration ($\beta = 0.676$, $p < 0.001$), which supports *H1*.

H2 was also supported by an immediate positive impact of green supply chain practices on competitive advantage ($\beta = 0.298$, $p = 0.012$).

Supply chain integration also had a substantial impact on competitive advantage ($\beta = 0.527$, $p < 0.001$), which supports *H3*.

The impact of green supply chain practices on competitive advantage based on the integration of supply chains was statistically significant ($\beta = 0.356$, $p < 0.001$). The direct effect was found to

Table 4. Measurement model assessment

Construct	Cronbach's alpha	Composite reliability	AVE
Green supply chain practices	0.912	0.938	0.708
Supply chain integration	0.887	0.922	0.747
Environmental uncertainty	0.841	0.899	0.690
Competitive advantage	0.873	0.915	0.729

Table 5. Discriminant validity

Construct	GSC	SCI	EU	CA
Green supply chain practices	0.842			
Supply chain integration	0.676	0.864		
Environmental uncertainty	0.521	0.498	0.831	
Competitive advantage	0.702	0.731	0.563	0.854

Table 6. Hypotheses testing

Relationship	Path coefficient	t-value	p-value	Decision
GSC → SCI	0.676	12.841	0.000	Supported
GSC → CA	0.298	2.517	0.012	Supported
SCI → CA	0.527	5.964	0.000	Supported

Table 7. Mediation results

Effect	Path coefficient	t-value	p-value	Decision
Indirect effect (GSC → SCI → CA)	0.356	5.733	0.000	Supported

Table 8. Moderation results

Interaction	Path coefficient	Standard error	t-value	p-value	95% CI lower	95% CI upper	Decision
GSC × EU → CA	0.172	0.074	2.318	0.021	0.027	0.317	Supported

be statistically significant even after mediator was added and thus an indication of partial mediation.

This interaction term between environmental uncertainty and green supply chain practices showed significance (β = 0.172, p = 0.021), and hence the effects of environmental uncertainty strengthened the positive association between the two variables, green supply chain practices and competitive advantage.

The relationship between green supply chain practices and environmental uncertainty and competitive advantage is positive and significant (β = 0.172, SE = 0.074, t = 2.318, p = 0.021, 95% CI [0.027, 0.317]). The confidence interval did not contain zero, so the interaction effect was upheld. The result corroborates the proposed H5 and indicates that perhaps green supply chain practices are more likely to positively influence the competitive advantage as environmental uncertainty escalates. Yet, the size of the interaction coefficient suggests that the effect of environmental uncertainty is incremental, and not dominant over other contextual factors.

Table 9. Simple slope analysis of environmental uncertainty

Level of environmental uncertainty	Conditional effect of GSC on CA
Low environmental uncertainty (–1 SD)	0.126
Mean environmental uncertainty	0.298
High environmental uncertainty (+1 SD)	0.470

The results of simple slope analysis showed that green supply chain practices positively associated with competitive advantage are stronger as environmental uncertainty grows. The estimated conditional effect rose with low, mean, and high environmental uncertainty as 0.126, 0.298, and 0.470, respectively. This indicates that environmental uncertainty has a positive moderating effect on the relationship between green supply chain practices and competitive advantage.

The coefficient of determination (R^2) of supply chain integration was 0.457, which implies that green supply chain practices explain 45.7 % of its variance. Competitive advantage had an R^2 of 0.642 that indicated the possibility of moderate to high explanatory power. Q^2 of supply chain integration and competitive advantage was 0.361 and 0.428, respectively, which indicates that the two variables are highly predictive.

4. DISCUSSION

The results show that all the hypothesized relationships were statistically valid; however, the interpretation of the results should take place within the boundaries of the sampled Jordanian manufacturing companies. The positive and significant relationship is theoretically in line with the Natural Resource-Based View and contingency-based reasoning but is not necessarily the same for all industries, firm sizes, or the nation as a whole. Therefore, it is important to understand that the characteristics of the sample and the sectorial context in which it is undertaken are important for the scope and boundaries of the findings.

The purpose of this study was to determine the mediating effect of supply chain integration and the moderating effect of environmental uncertainty on the relationship between green supply chain practices and the competitive advantage of manufacturing firms in Jordan. The findings confirm all formulated hypotheses and show that green supply chain practices can bring in competitive advantage both directly and indirectly through supply chain integration. The results also reveal that the relationship between green supply chain practices and competitive advantage is strengthened in the presence of environmental uncertainty.

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The first result indicates that adoption of green supply chain practices has a positive and significant impact on supply chain integration. The result suggests that implementing environmental practices increases the chance of firms improving coordination, information sharing, and collaboration within their supply chains. In the real world, engaging in green purchasing, eco-design, environmental cooperation, and waste reduction requires more co-operation and communication between internal departments, suppliers, and customers. The result is similar to the findings of the prior research, which indicates that adopting sustainability-related supply chain activities helps companies to enhance coordination and integration with supply chain partners (Duong & Ha, 2021; Javed et al., 2026). The discovery also supports the Natural Resource-Based View, as green practices seem to be adding value when they are integrated into organizational and inter-organizational activities.

The second result shows that the practices within the green supply chain have a significant positive impact on competitive advantage. Environmentally responsible practices in the supply chain can assist manufacturing companies to reduce costs, make them more differentiated, responsive, and market-positioned. These findings align with prior research showing that green practices can boost operational performance, reputation, and long-term competitiveness (Muhammad & Saad, 2023; Romagnoli et al., 2023; Singh et al., 2025). This differs from the studies that emphasize the financial burden and the short-term performance risk of environmental investments (Orji et al., 2024; Schilling & Seuring, 2024; Febrianto & Rufaidah, 2026). The difference can be accounted for by the nature of green practices being more valuable when companies use them strategically, instead of only as compliance practices.

The third result indicates a significant positive contribution of supply chain integration to competitive advantage. This discovery indicates that integration can help companies achieve operational alignment, minimize duplication, facilitate more efficient information sharing, and respond more quickly to market and customer demands. This aligns with previous studies that found that integrated supply chains improve responsiveness, efficiency, coordination, and competitive outcomes (Rahman et al., 2026; Sohu et al., 2026). This finding is particularly relevant to Jordanian manufacturing companies, as resource-constrained companies might require more coordination with their suppliers and customers to achieve competitive results.

Partial mediation is found between green supply chain practices and competitive advantage in the mediation results. Thus, green supply chain practices have a positive direct effect on competitive advantage, and also a positive indirect effect by enhancing the integration of supply chains. The partial mediation result is important as it provides an explanation of how sustainability-focused practices become competitive. The result builds on the previous study on green supply chain practices as directly influencing performance or competitive advantage (Roy et al., 2020; Agyabeng-Mensah et al., 2021; Rashid et al., 2025). It indicates that integration capability is essential for firms to fully realize the benefits of green practices. Thus, the finding gives credence to the claim that value grows with complementary organizational resources and skills when it comes to environmental resources.

The moderation result shows that the relationship between green supply chain practices and competitive advantage is reinforced by environmental uncertainty. This discovery suggests that green practices are more strategically important if companies are under regulatory shifts, market uncertainty, technological innovations, and competition. In the context of uncertainty, green practices can enable firms to increase their resilience, differentiation, adaptability, and stakeholder trust. This finding is consistent with contingency theory, which states that the effectiveness of strategic practices is contingent on the external environment. Results of the moderation analysis indicate that the positive relationship between green supply chain practices and competitive advantage can be stronger in the companies under study when environmental uncertainty is high. The positive interaction coefficient proved statistically significant, but not very strong, meaning that environmental uncertainty is an incremental and not a dominant boundary condition. Simple slopes analyses also revealed that the estimated relationship was greater when levels of environmental uncertainty were higher. However, one should be careful in interpreting this result since all the dependent, independent,

and mediating variables were self-reported by the same person at a single time. It is also in line with previous studies which indicated that dynamic and uncertain environments result in high values of adaptive and sustainability-oriented capabilities (Wilden et al., 2013; Valashiya & Luke, 2023; Magdy & Elmakkawy, 2025). Uncertainty may even make green supply chain practices more relevant in the Jordanian manufacturing environment, as firms have to meet environmental expectations while competing for business.

The results together give theoretical and practical insights. Theoretically, the study also attempts to explain how, in the context of green supply chain practices, the circuit could provide a strategic resource that could provide a competitive advantage when integrated into the supply chain. This study also supports contingency theory as it shows that the value of green supply chain practices is reinforced in the presence of environmental uncertainty. Managerial implications of the findings are that managers should not consider green supply chain practices as environmental measures by themselves. Rather, they should link them to supplier integration, customer integration, internal coordination, and information sharing. Managers should also consider that ambiguous environments could make green initiatives more strategic, particularly if companies employ them as a means of becoming more resilient, responsive, and differentiated.

From a general perspective, the discussion indicates that a green SCP can be a source of competitive advantage for manufacturing companies in Jordan in general, but with more power when the companies have integration capabilities and are working under conditions of uncertainty. This implies sustainability must be part of the supply chain strategy and not stand alone as an environmental responsibility.

CONCLUSION

The aim of this study was to explore the relationship between green supply chain practices and competitive advantage among Jordanian manufacturing companies, where supply chain integration was used as a mediator and environmental uncertainty as a moderator. The results indicate that the green supply chain practices of the surveyed companies are positively associated with supply chain integration and competitive advantage. The association between green supply chain practices and competitive outcomes was also found to be partially mediated by the relationship with integration of the supply chain, which also had a positive association with competitive advantage.

Additionally, results indicate that perhaps the relationship between adopting green supply chain practices and competitive advantage could be stronger at higher levels of environmental uncertainty. It should be taken as a statistical association rather than a direct causal link between environmental uncertainty and the competitive advantage of green practices, however. Overall, the results indicate that adopting "green supply chain practices" can lead to competitive advantage if proper coordination, information sharing and collaboration are seen among internal functions, suppliers and customers. The results also suggest that the strategic benefits of environmentally related activities might be more significant when companies face a changed regulatory, market, technology and competitive environment.

Manufacturing companies have a management point of view to consider: green purchasing, eco-design, waste reduction, recycling and environmental cooperation could be integrated into more general supply chain integration. Managers will therefore need to pay particular attention to enhancing internal coordination and collaboration with suppliers and customers during the implementation of environmental efforts. However, such recommendations should be understood as implications, not confirmed causal prescriptions, based upon statistical associations.

The study has some limitations. It used a cross-sectional design and was based on self-reported data from a single management informant per firm. The 254 valid responses were from 254 different manufacturing businesses, with no business providing more than one questionnaire. But the one-informant

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design can also give rise to perceptual and common method biases. Moreover, the non-random purposive sampling and attention to Jordanian manufacturing firms have limited the generalization of the results. Furthermore, the three global indicators for the measurement of supply chain integration were perceived integration indicators only, and did not provide a full multi-dimensional measure of internal, supplier, and customer integration.

Future studies could use a longitudinal or time-lagged design to see if the relationships found here are stable over time and for more rigorous evidence of the order of the relationships. Research could also address variables such as having more than one respondent per firm, integrating perceptual data with objective data on performance, and using probability sampling, if possible. Future researchers can consider internal, supplier, and customer integration as separate first-order dimensions or as a higher-order construct. The results of the study might be extended to other countries, industries, and firm sizes using comparative studies. More mediating and moderating factors such as digital capability, green innovation, supply chain resilience, and regulatory pressure can be more explanatory of the relationship between green supply chain practices and competitive advantage.

AUTHOR CONTRIBUTIONS

Conceptualization: Ahmad Ali.
Methodology: Ahmad Ali, Rany Abu Eitah.
Data curation: Ahmad Ali.
Formal analysis: Ahmad Ali.
Investigation: Ahmad Ali, Rany Abu Eitah.
Validation: Ahmad Ali, Rany Abu Eitah.
Visualization: Ahmad Ali.
Writing: original draft: Ahmad Ali.
Writing: review & editing: Ahmad Ali, Rany Abu Eitah.
Supervision: Ahmad Ali.

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APPENDIX A. Questionnaire items

Table A1. All items were measured using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree

Construct	Code	Questionnaire item
Green supply chain practices	GSC1	Our firm considers environmental criteria when selecting suppliers.
Green supply chain practices	GSC2	Our firm adopts eco-design principles in product and process development.
Green supply chain practices	GSC3	Our firm cooperates with suppliers and customers to reduce environmental impact.
Green supply chain practices	GSC4	Our firm implements waste reduction and recycling practices in its operations.
Supply chain integration	SCI1	Our firm effectively shares relevant information across internal departments.
Supply chain integration	SCI2	Our firm collaborates closely with key suppliers to improve supply chain coordination.
Supply chain integration	SCI3	Our firm collaborates closely with key customers to improve responsiveness and service quality.
Environmental uncertainty	EU1	Changes in environmental regulations are difficult to predict.
Environmental uncertainty	EU2	Market conditions in our industry change rapidly.
Environmental uncertainty	EU3	Technological developments in our industry are frequent and unpredictable.
Competitive advantage	CA1	Our firm achieves cost efficiency compared with competitors.
Competitive advantage	CA2	Our firm offers differentiated products or services compared with competitors.
Competitive advantage	CA3	Our firm responds quickly to changes in customer and market requirements.

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