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Supply chain integration and green innovation, the role of environmental uncertainty: Evidence from Jordan

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Prior research in several industries, particularly manufacturing industries, has confirmed the use of supply chain integration (SCI) to achieve green innovation (GI). Despite this, there has been very little research into the effects of SCI on the GI of manufacturing businesses. As a result, the current study was carried out to close this gap in the literature. Data from 231 manufacturing businesses in Jordan was used to validate a framework of several hypotheses about the relationships involving SCI and GI. SCI (customer integration (CI) and supplier integration (SI) have beneficial benefits on the green product and process innovation (GPDI & GPRI), according to the results of structural equation modeling. SI's effects on green products and process innovation are moderated by environmental unpredictability. The effects of CI on green product innovation are being moderated by environmental unpredictability. Environmental uncertainty, on the other hand, does not moderate the impacts of CI on green process innovation. This research adds to our knowledge of the SCI-GI link.

1. Introduction

The business climate has changed dramatically over the last two decades, and organizations must use their resources, as well as their expertise of suppliers and consumers, to improve their performance in this unstable and dynamic environment (Cao & Zhang, 2011). Stakeholders' growing concern for the environment is placing pressure on companies to choose structures that value ecological sustainability over traditional profit models (Chang, 2011). Nowadays, environmental sustainability is becoming an increasingly significant component influencing a company's growth. Companies are forced to be environmentally responsible by pressures from interest groups such as governments, consumers, competitors, and others (Yang & Lin, 2020). As a result of this circumstance, an increasing number of businesses have been pushed to implement GI to safeguard the environment while also growing economically (Sun & Sun, 2021).

GI has been proposed as a strategic strategy for maintaining sustainability while gaining a competitive edge, according to researchers (Liu, 2020). GI is a key driver of long-term development and a tool for decreasing negative environmental consequences at every phase of the product life cycle. As a novel innovation approach, GI has the potential to successfully address pollution control, energy conservation, and green technology boosting (Wu, 2013; Sun & Sun, 2021). GI is being viewed as a potential means of achieving economic development and sustainability at the same time because of its focus on new market entrance plans, product differentiation, strong managerial competencies, and cost-cutting initiatives (Qu and Liu, 2022).

GI aims to improve environmentally sustainable goods and processes that already exist (Rehman et al., 2021). Choosing ecologically friendly raw materials, eliminating waste, making products that follow sustainable building principles, and lowering water and electricity use are all examples of green innovation. This enables businesses to contribute to

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environmental sustainability and has a beneficial influence. Most prior scholars have split GI into two categories: GPDI and GPRI (Lisi et al., 2020; Qu & Liu, 2022). Companies, on the other hand, cannot rely entirely on their initiatives to execute GI efficiently, especially in the case of complex manufacturing supply chains, businesses require assistance from existing supply chain partners (Zailani et al., 2015). To deploy green innovations, supply chain partners must share research and innovation expenditures and spread the risks posed by innovative products and processes. As a result, green innovation-based integrative processes are an excellent method for organizations to balance sustainable development and increase competitiveness (Yang and Lin, 2020). Firms involve their supply chain partners, such as suppliers and consumers, in supply chain activities. Because it is a key part of supply chain integration, it has been proved that external (supplier, customer) and internal integration successfully boost business performance (Wong et al., 2011; Wu, 2013; Vaaland & Heide, 2007).

At the very same period, SCI boosts innovation capabilities, allowing customers to receive new value, according to Resource Dependent Theory (RDT), organizations can achieve a competitive edge by integrating with supply chain partners and obtaining essential resources (Lo et al., 2018; Wong et al., 2013). Companies that effectively execute environmental policies would interact more efficiently with supply chain partners to exchange resources and knowledge to solve environmental problems, according to Resource Dependent Theory (RDT) (Doganova and Karnoe, 2015). SCI can improve companies' bilateral relationships with supply chain partners, facilitate information exchange, and improve the implementation of environmental-related activities, lowering operational cost, providing a sustainable competitive advantage, and ultimately bringing economic benefits to businesses. GPDI & GPRI may be embraced by companies by learning from their supply chain partners since both the supplier and customer relationship has been found to favorably impact (GPDI & GPRI) (Lo et al., 2018).

Some situational concerns, such as environmental unpredictability, may influence the success of customer/supplier engagement in GI. Because it comes from a variety of sources, environmental uncertainty is complicated. As a result, there must be a difference drawn between all those effects on supply chain management (Lee et al., 2009; Land et al., 2012).

Environmental uncertainty, on the other hand, is said to have an altering influence on the effect of external integration in green product creation, according to the contingency theory (Srinivasan et al., 2011). In recent years, there has been a lot of interest in tying GI and SCI together. However, in established economies in general and emerging economies in particular, insufficient work has been done to connect these two themes (Yang & Lin, 2020).

As a result, the study built a more thorough research framework to clarify the influence of SCI on GI in industrial enterprises in Jordan, taking into account the modifying function of environmental uncertainty. Previous research that used a one-dimensional technique varied from this one. SCI was classified into two categories in this study: supplier integration and customer integration. It also concentrated on green innovation, which was divided into two categories: (GPDI & GPRI).

Environmental uncertainty was also considered a moderating factor in this study. Jordan was chosen for this study for a variety of reasons. For starters, in 2016, Jordan began to take GI seriously (National Strategy and Action Plan for Sustainable Consumption and Production in Jordan 2016-2025). Second, Jordan is one of the countries that lack resources such as water, energy, and minerals, thus addressing the issue of sustainability (whether environmental or social) is both a necessity and a strategic decision. Third, Jordan is one of the region's most advanced countries in terms of environmental and ecological legislation, forcing businesses to consider environmental concerns.

1.1 Green innovation

GI contributes to the creation of environmentally conscious processes that involve the utilization of green raw materials, adherence to environmental design principles, reduced material use, reduced pollutant emissions, and reduced water, electricity, and other raw - materials consumption (Wang, et al., 2022). GPDI is the design, manufacture, and marketing of a product that has no or minimal negative impact on humans or the environment throughout its life cycle, or the change of a product's design to reduce environmental impact and enhance energy efficiency (Junaid et al., 2022). GPDI refers to the incorporation of green concepts into product (re)design and packing to improve product quality and distinction. Green product design often entails significant improvements in product technology, materials, and design, and innovation is frequently equated with environmentally responsible product design (Wong et al., 2020). GPRI, on the other hand, refers to technological and process advancements that lead to the production of products that have no or minimal environmental impact. In addition to lowering energy consumption in the manufacturing process, lowering waste gas emissions, lowering wastewater discharge, lowering water consumption, and increasing resource and energy efficiency are also important goals. GI is not simply a good approach to cope with environmental issues, but it's also a good way to boost total production by utilizing resources and energy more efficiently (Wang, et al., 2018).

1.2 Supply Chain Integration

SCI is defined in the literature as the synchronization and interrelatedness of organizational processes that encapsulate communications across multiple channels and their linkage with the supply network, which involves supplier, distributor, and retailer until the product reaches the consumer, as an indicator of supply chain performance competitiveness (Siagian et al., 2021). SCI may be defined as the alignment and coordination of the supply chain, therefore it necessitates cooperation, coordination, and alignment to guarantee that everyone is working toward the same goal (Alzoubi et al., 2022). Manufacturing businesses have deliberately begun to implement the SCI method in order to deliver value to customers and produce mutual benefits for all supply chain participants (Zhao et al., 2018; Kong et al., 2020). Internal SCI and external SCI are the two types of supply chain integration. Internal integration refers to active and prompt interaction, collaboration, cooperation, and synergy between various cross-functional operations within the supply chain, as facilitated by the interaction technique (Alzoubi et al., 2022). External integration involves maintaining constant and beneficial communication, cooperation, and collaboration with suppliers, consumers, and other partners, as well as forming long-term relationships and strategic alliances. The ability of a company to interact and integrate with suppliers can aid in the discovery of new sources and the improvement of the quality of raw goods delivered (Paul & Chowdhury, 2020; Christopher, 2000). Companies can receive more precise information and give faster information to suppliers of raw materials by integrating with external customers. Building ties among supply chain partners to communicate useful knowledge about recent markets, products, consumers, and potential markets can be a strategic choice (Zhao et al., 2018).

1.3 Relation between external SCI and GI

Knowledge transfer has been identified as an important element of enhancing product development in the contemporary innovation literature. Customers and suppliers, according to reductionism, represent the external environment, while the company's functions reflect the internal environment (Wong et al., 2011). This method enables us to comprehend the impact of external cooperation and integration on internal operations. Companies' principal strategy in responding to rising environmental challenges is to launch green products, green product innovation, on the other hand, is primarily reliant on data gathered from customers and suppliers (Zhao et al., 2018). Previous research suggests that focusing on competencies and collecting external information can help businesses enhance their innovation performance (Zhou & Li, 2012; Awan et al., 2021). External integration aids procedures and processes such as acquiring correct supply and demand data, which is critical for successful product innovation. Low levels of customer and supplier interaction make it more probable that the company would obtain false or misleading information, leading to a lower degree of GI (Zhao et al., 2018). Integration approaches with consumers are used to expand the capabilities of information processing to better understand markets. Sharing knowledge with consumers about environmental objectives, behaviors, and policies, as well as smart production techniques and their impact on the product life cycle, is part of consumer integration (Wang et al., 2018; Zhu et al. 2008).

Customers are far more aware of difficulties, which encourages proactive supplier measures, leading to better and lasting relationships with customers. Customer integration can improve supply chain partners' mutual understanding, cooperation, and coordinated activities to solve issues and reach environmental goals collaboratively (Wu, 2013; Wong et al., 2020). Furthermore, integrating with consumers promotes knowledge and know-how exchange, assists organizations in resolving disputes, and boosts innovation efforts (Lau et al., 2010; Koufteros et al., 2005). Closed-loop procedures and logistics planning activities benefit from collaboration and information sharing. Increased information capacity aids in identifying and influencing customer wants, and this additional information can be used to improve green product design, packing, and logistical actions (Wong et al., 2020). External customers play a vital role in motivating enterprises to embrace green process methods and green product innovation, the more integrated a company's supply chain is the better its GI skills (Song et al., 2018). Customer involvement has a direct influence on green performance (Pham & Pham, 2021). According to Zailani et al. (2015), market demand has a favorable effect on GI activities. According to Yang and Lin's 2020 study, supply chain interactions have a significant consequence on GI performance. Sustainable customer integration improves GPRIs (Junaid et al. 2022). Melander (2018) shows that in the industrial market, organizations that collaborate with consumers may generate green products.

Businesses that have customer involvement have been able to improve GI (product, process) (Qu & Liu, 2022). While some studies have found that green customer integration has a direct impact on green (product, process) innovation, and an indirect impact on green (product, process) innovation (Wong, 2020; Kong et al., 2020). On the other hand, customer interaction has a favorable influence on green product innovation (Zhao et al., 2018). This leads us to the following assumptions:

H_1: *Customer integration is positively associated with GPRI.*
H_2: *Customer integration is positively associated with GPDI.*

Supplier integration is the practice of collaborating with large suppliers to develop shared business processes and solve problems to obtain strategic gains (Qu & Liu, 2022). Companies' potential to innovate expands when they interact and incorporate their resources with suppliers, as suppliers participate significantly in boosting GI Suppliers' information-sharing capabilities, improving environmental collaboration among supply chain partners, eliminating information asymmetry, and improving supply chain environmental practices (Pham & Pham, 2021). Close collaboration with suppliers and information sharing decreases uncertainty and risks, allowing the company to quickly develop goods and penetrate emerging markets since green innovations necessitate massive amounts of data (Lau et al., 2010). Companies must track, monitor, and manage information linked to green practices using high-capacity information processing systems. As a result, businesses must work closely with their suppliers to help them become more environmentally friendly by providing helpful support and guidance, as well as offering their expertise and knowledge (Chiou et al., 2011).

Close integration with major suppliers can increase a company's data processing efficiency and capacity by introducing new information treatment units outside the organization and reducing overload of information. This synthesis can combine complementary knowledge and experience with parts and components to boost green technologies (Qu & Liu, 2022). As a result, high-level supplier interaction can improve information processing's capabilities and efficiency, allowing it to better manage the demanding tasks connected with the GPDI process. Supplier integration improves a manufacturer's ability to initiate a new green product development, (Lee & Kim, 2011; Freije et al., 2021). Supplier integration has a clear influence on environmental performance (Pham and Pham, 2021). Green supplier integration, according to Du et al. (2018), has a direct influence on environmental performance. Junaid et al. (2022) found that integrating sustainable suppliers improves GPRI. Green SCI promotes green (product, process) innovation (Aisjah & Prabandari, 2021; Wu 2013). According to (Melander & Pazirandeh, 2019; Qu and Liu, 2022) organizations that collaborate with suppliers are more likely to develop green products, and those that incorporate with suppliers are more likely to develop green (product, process) innovation. While Wong (2020) found that Green supplier integration did not affect (product, process) innovation. Supplier interaction has a favorable effect on green product creation (Zhao et al., 2018). This leads us to the following assumptions:

H$_3$: *Supplier integration is positively associated with GPRI.*
H$_4$: *Supplier integration is positively associated with GPDI.*

1.4 The moderating effect of environmental uncertainty

Environmental uncertainty is described as the consequences of inaccurate environmental change projections on businesses or the difficulty of precisely anticipating the result of decisions. Environmental uncertainty is caused by a variety of elements such as vendors, suppliers, customers, and rivals (Paulraj & Chen, 2007; Wu, 2013). In marketing and product development process research, ambiguity is an important concept. Because information flows encompass several lines of contact in the supply chain, complexity is an underlying condition in interactions between businesses, making it difficult to assess the causation of linkages between distinct activities (Zhao et al., 2018). Environmental conditions, according to contingency theory, push organizations to align their processes and structures with their performance goals. To overcome the uncertainty in their environment, organizations generally use several techniques to mold their workplace environment (Huang et al., 2014; Kalyar et al., 2020). As a result, according to contingency theory, environmental unpredictability may alter the relationship between external supply chain incorporation and GI. Various sources of environmental uncertainty include demand uncertainty and technology uncertainty. Companies should examine different sources of uncertainty to see how they affect SCI and GI (Land et al., 2012; Koufteros et al., 2005; Zhao et al., 2018).

Companies must perform rich and additional information processing due to the high level of environmental uncertainty, resulting in a growing need to enhance information processing capacity and match it to the company's information needs, leading to environmental uncertainty (Bode et al., 2011). This necessitates the involvement of third-party activities to boost information processing capability in GI to lower high levels of ambiguity. According to the literature, firms flourish or fail since managers make judgments based on their beliefs and available facts (Wong et al., 2011; Koufteros et al., 2005). It is vital to differentiate between the mechanisms of consumer and supplier participation that drive GPD to understand the changing impact of environmental uncertainty. The degree of variation and change in demand, or the failure to foresee consumer needs and requirements, is measured by demand uncertainty (Kong et al., 2020). The primary goal of including suppliers and customers in GI is to learn about their needs and preferences. Companies attempt to improve their information processing capabilities to survey markets and estimate demand changes in the face of environmental uncertainty (Eisenhardt et al., 2010).

Companies must improve customer and supplier involvement, monitor markets to reduce prediction mistakes, and change supply chain activities and GI plans to satisfy market demand fast when environmental uncertainty is high. Companies must encourage GPDI to compete in the marketplace and better match customer demands and preferences (Land et al., 2012; Wong et al., 2011; Wu, 2013). According to several research, organizations that are successful in dealing with changing client wants and wishes are better able to exchange information with them and create strategic alliances with them (Huang et al., 2014; Zhao et al., 2018). Wu, (2013), noted that demand uncertainty affects the relation between SCI (supplier integration, customer integration) and GI (product innovation, process innovation).

Zhao et al. (2018) found that technological uncertainty boosts the influence of customer and supplier involvement in green product development. The association between consumer engagement and green product creation was unaffected by demand uncertainty. As a result, consumer and supplier participation is much more likely to be linked to GI when demand uncertainty is high (Wong et al., 2011). Environmental unpredictability moderates the link between industry dynamics and new product creation (Augusto & Coelho, 2009). This leads us to the following assumptions:

H$_5$: *Environmental uncertainty moderates the relationship between customer integration and GPRI.*

H6: *Environmental uncertainty moderates the relationship between customer integration and GPDI.*
H7: *Environmental uncertainty moderates the relationship between supplier integration and GPRI.*
H8: *Environmental uncertainty moderates the relationship between supplier integration and GPDI.*

1.5 Control variables

We adjusted for company age and size in this study since big enterprises may have more capabilities to adopt developments (Grant et al., 2002) and more capacity to implement green projects (Wu et al., 2013). Furthermore, a company's age may make it easier to obtain external resources for the expansion of its infrastructure. Firm age, according to Zhao et al. (2018), permits organizations to gather more knowledge and information from their external environments, allowing them to produce more imaginative solutions. In our research, we included control variables such as firm age and size that could determine green innovation.

2. Methodology

2.1 Sampling and data collection

To test the research hypotheses, 600 companies were chosen, most of which are located in industrial parks in Jordan (https://www.jiec.com/en/page-81/). The information was gathered in three stages. We created a questionnaire based on past research and then tweaked it to make it relevant to the Jordanian setting. We did a trial test before launching the formal survey. A small number of firms (n = 6) were randomly selected for the pilot project. This step was taken to ensure that the scale items were clear and succinct. These firms' top or intermediate managers were interviewed, but their comments were not included in the final analysis. The questionnaire was changed in response to comments from the pilot study. Second, the sampled companies were chosen based on suggestions from local institutions to guarantee the accuracy and thoroughness of the responses. We provided the informants a free report depending on our findings to entice them to participate. Finally, the questionnaire was delivered to the best-suited informants by email or postal mail, together with a cover letter detailing the research's goals. Two reminder mailings or phone calls were sent out after the initial invitation. To boost the response rate, follow-up phone calls were done every three weeks. This resulted in 231 viable surveys being returned, resulting in a 38.5 percent usable response rate.

2.2 Questionnaire development

All of the items were taken from earlier research and tweaked to fit the needs of this study. Adopted from (Qu & Liu, 2022; Wong et al., 2013; Du et al., 2018). Customer and supplier integration each includes five items, with a focus on collaboration and communication with both customers and suppliers. We used four items to quantify environmental uncertainty, including "our primary production schedule has a substantial proportion of fluctuation in demand," which we borrowed from (Zhao et al., 2018; Paulraj & Chen, 2007; Du et al., 2018, Wu, 2013). "Our suppliers consistently meet our specifications," the company claims, adding that "our sector is characterized by rapidly evolving green technology." The four components utilized to measure GPDI were "producing and creating sustainable packaging for new and existing products," "restoration of our end-of-life products and recycling," and "restoration of our end-of-life products and recycling" (Qu and Liu, 2022; Melander, 2018; Zhao et al., 2018; Awan et al., 2021). GPRI was assessed using a four-item scale adopted from (Lisi et al., 2020; Qu and Liu, 2022). Respondents were asked to rate the degree of innovation in environmental processes. The questionnaire employed a 5-point Likert scale, with 1 representing strongly disagree and 5 signifying strongly agree. The natural logarithm of the number of employees was used to calculate the size of the company. The age of a company is significant since older companies are more likely to remain inactive. The natural logarithm of the number of years since the company was created was used to calculate its age (Wu et al., 2013; Zhao et al., 2018; Lisi et al., 2020).

2.3 Construct validity and reliability

The reliability was tested using Cronbach's alpha and composite reliability (Fornell & Larcker, 1981). Cronbach's alpha for all elements ranged from 0.841 to 0.943, while composite reliability scores varied from 0.852 to 0.942, according to Table 1. As a result, these indicators reveal that the scales are dependable and that all of the variables that meet the 0.70 threshold items had high loadings (greater than 0.5). For each construct, we can ensure that the indications are internally consistent. In addition, the average variance extracted (AVE) of all the variables was determined to ensure convergent validity (Fornell & Larcker, 1981). The average variance extracted (AVE) of all the constructs, as shown in Table 1, is greater than 0.50, with values ranging from 0.604 to 0.813. This shows that the variables incorporated in the model have convergent validity. The Fornell and Larcker criterion was employed to assess discriminant validity. The square root of the AVE measure is bigger than the correlations between the variables, implying discriminant validity, as seen in Table 2.

Table 1
Measurement model results

Items	Factor loading	CR	AVE	α
Supplier Integration				
SI1	0.896	0.937	0.762	0.937
SI2	0.886			
SI3	0.866			
SI4	0.836			
SI5	0.866			
Customer Integration				
CI1	0.806	0.930	0.737	0.928
CI2	0.905			
CI3	0.866			
CI4	0.876			
CI5	0.836			
Environmental Uncertainty				
EU1	0.816	0.852	0.604	0.841
EU2	0.627			
EU3	0.896			
EU4	0.816			
Green Product Innovation				
GPDI1	0.886	0.933	0.786	0.932
GPDI2	0.876			
GPDI3	0.876			
GPDI4	0.896			
Green Process Innovation				
GPRI1	0.925	0.942	0.813	0.943
GPRI2	0.905			
GPRI3	0.866			
GPRI4	0.896			

Table 2
Inter-correlation of constructs

	Variable	1	2	3	4	5
1	**Supplier Integration**	**0.763**				
2	**Customer Integration**	0.104	**0.762**			
3	**Environmental Uncertainty**	0.116	0.137	**0.796**		
4	**Green Product Innovation**	0.340	0.300	0.204	**0.701**	
5	**Green Process Innovation**	0.297	0.320	0.192	0.345	**0.738**

The diagonal (bold) numbers are the square root of the AVE

3. Results

A structural Equation is a mathematical formula that describes the structure of building the model hypotheses which was used to test our hypotheses. The Goodness-of-Fit indices for the structural model are higher than recommended values, with the model (1) fitting at 2/df= 1.07, RMSEA = 0.0378, SRMR=0.0846, CFI=0.985, and TLI=0.946. Furthermore, the model (2) fit indices were 2/df= 1.22; SRMR=0.042; RMSEA=0.0915; CFI=0.940; TLI=0.936, which all exceeded Hu and Bentler (1999) proposed threshold values.

Table 3
Regression Results

Path	Model I		Model II	
	β	t value	β	t value
CI→GPRI	0.268	3.359**	0.262	3.295**
CI→GPDI	0.172	2.218*	0.168	2.105*
SI→GPRI	0.231	2.718**	0.228	2.697**
SI→GPDI	0.204	2.531**	0.197	2.409**
EU→GPRI			0.161	2.104*
EU→GPDI			0.173	2.115*
CI*EU→GPRI			0.131	1.643
CI*EU→GPDI			0.196	2.641*
SI*EU→GPRI			0.188	2.224*
SI*EU→GPDI			0.177	2.183*
Firm Age →GPRI	0.179	2.152*	0.191	2.112*
Firm Age →GPDI	0.185	2.196*	0.178	2.168*
Firm Size →GPRI	0.168	2.124*	0.164	2.107*
Firm Size →GPDI	0.175	2.196*	0.170	2.142*
Note:*p< 0.05; **p< 0.01	$\chi2$ /df = 1.07; SRMR=0.0846; RMSEA=0.0378; CFI=0.985; TLI=0.946		$\chi2$ /df = 1.22; SRMR=0.042; RMSEA=0.0915; CFI=0.940; TLI=0.936	

3.1 Direct effect

The results of model 1 (Table 3) reveal that customer integration has a considerable effect on GPRI ($\beta = 0.268$, t= 3.359, $p < 0.01$), supporting H1. Customer integration also considerably enhanced GPDI ($\beta = 0.172$, t= 2.218, $p < 0.05$), supporting H2. The paths from supplier integration to GPRI ($\beta = 0.231$, t= 2.718, $p < 0.01$) and GPDI ($\beta = 0.204$, t= 2.531, $p < 0.01$) are both statistically significant, implying that H3, H4 are supported.

3.2 Moderation effects of Environmental Uncertainty

The interaction effect of environmental uncertainty and customer integration is not significantly associated with GPRI ($\beta = 0.131$, t = 1.643, $p > 0.05$), according to the results of model 2 (table3). GPDI is significantly related to the interaction term of environmental uncertainty and consumer integration ($\beta = 0.196$, t= 2.641, $p < 0.05$), As a result, H5 was not supported, although H6 was. Furthermore, the results of model 2 demonstrate that the interaction term of environmental uncertainty and supplier integration is connected with GPRI ($\beta = 0.188$, t= 2.224, $p < 0.05$) and GPDI ($\beta = 0.177$, t= 2.183, $p < 0.05$). As a result, hypotheses H7 and H8 are both supported.

3.3 Control variables

For the two control variables considered in this study (table 3), both coefficients are statistically positive, implying that greater GI for larger and older organizations may be related to economies of scale, while businesses with greater education staff may be owing to high learning abilities.

4. Discussion

According to the findings, customer integration looks to help (GPDI & GPRI). With a high level of customer integration, the company will be able to actively watch and fulfill its customers' demands and preferences, allowing it to successfully manufacture innovative green products or green production methods. Customers' willingness to collaborate with companies and seek their input on their needs and demands, as well as their involvement in the structure and improvement of products and the demonstration of preliminary designs to them, aids in identifying customer tastes and desires and enhancing them in new products. This result is consistent with research findings (Freije et al., 2021; Yang & Lin, 2020; Junaid et al., 2022; Song et al., 2018; Aisjah & Prabandari, 2021; Wu, 2013; Wong et al.. 2020; Zhao et al., 2018; Du et al., 2018; Koufteros et al., 2005; Qu and Liu, 2022; Lisi et al., 2020).

The findings suggest that supplier integration can help the organization improve its GI in both product and process areas. A high degree of supplier integration can result in sharing knowledge and enhance the company's ability to digest information and integrate it with suppliers' complementing knowledge and experience to build new green initiatives and innovations successfully. This conclusion differs from previous research findings (Freije et al., 2021; Wong et al.; 2020; Koufteros et al., 2005). It is consistent with the findings of investigations (Yang and Lin, 2020; Junaid et al., 2022; Song et al., 2018; Aisjah and Prabandari, 2021; Wu, 2013; Lee and Kim, 2011; Zhao et al., 2018; Du et al., 2018; Awan et al., 2020; Qu and Liu, 2022; Chiou et al., 2011; Lisi et al., 2020). Elmansi (2015), on the other hand, feels that firms' eagerness to include suppliers in supply chain operations offers suppliers the opportunity to express their ideas that aid in product enhancement. In addition, if the essential resources are unavailable, alternate materials should be suggested, as well as new approaches to create designs more viable.

This study demonstrates that incorporating green needs into a company's operating model can lead to improvements (GPDI & GPRI). From design concepts to prototype development, the vendor was involved in the development of innovative green products at every stage. The purchasing firm (maker) became involved when the supplier possessed a critical technological capability that the acquiring firm (manufacturer) lacked as a core competency. Firms must be able to communicate, collaborate, and seamlessly integrate with upstream suppliers and downstream customers to develop their creative capacities and achieve their environmental goals.

As a result of this type of integration, more possibilities to enhance strategic advantage in global marketplaces may exist. As a result, companies must invest significant resources in optimizing the value of information and expertise received from customers and suppliers, as well as coordinating their efforts with suppliers and customers to create green technology and solve environmental concerns. In practice, businesses can provide support and education to their suppliers to help them improve their technical capabilities and safeguard the environment. To promote customer integration, it is vital to understand consumer challenges and environmental considerations through active market information gathering and effective collaboration amongst organizations.

Environmental uncertainty alters the relationship between supplier integration, green product innovation, and GPRI, according to the study's findings. Furthermore, the findings revealed that the relationship between consumer participation and green product creation is influenced by environmental uncertainty. This finding is in line with the principles of contingency theory (CT) and Organizational Information Processing Theory (OIPT), as well as research findings (Augusto and Coelho, 2009; Wu, 2013). It also differs from the findings of a study (Lisi et al., 2020; Kalyar et al., 2020; Zhao et al., 2018; Koufteros et al., 2005). When confronted with a significant level of environmental uncertainties, the need to engage key consumers and suppliers in GI becomes even more important to assure its success in the marketplace. When faced with increasing uncertainty, Wong et al. (2011) found that integration and interaction with other parties are more critical, and our findings show that both suppliers and customers are more involved. This demonstrates the necessity for the organization to connect external customers and suppliers to enhance the capability to handle the information to meet the capacity to handle information and the demand for it.

Environmental uncertainty did not affect the relationship between customer integration and GPRI, according to the findings. We conducted additional interviews with chosen managers from Jordanian manufacturing companies to assess the interpretation of this result and gain a better understanding of it. When there is less ambiguity, interviewees noted, it is comparatively easy to address client expectations. In this situation, there isn't much of a requirement for a close consumer connection. Customers may keep the company captive to their notions about the production process, which may not be practical and difficult to apply intoioneer breakthroughs if there is a lot of uncertainty. This outcome is consistent with the findings of a study (Zhao et al., 2018; Kalyar et al., 2020; Koufteros et al., 2005). It also differs from the outcome of a study (Wu, 2013; Lisi et al., 2020).

The findings revealed that the controlling variable, company size, has an impact on green innovation. This can be explained by the fact that large corporations have further resources than small companies and have more flexibility in allocating resources to supply chain activities, whereas small companies may not. Larger businesses might also have more negotiating power with suppliers. Large enterprises' high-level GI could be attributable to economies of scale. This conclusion is consistent with previous research (Kong et al., 2020; Qu and Liu, 2022), but differs from previous research (Lisi et al., 2020). According to the findings, the age of the organization has an impact on green innovation. Older companies can gather more information and knowledge from the outside world, resulting in a more knowledgeable and learning strategy to deal with green innovations. This result is consistent with research findings (Qu and Liu, 2022; Kong et al., 2020; Awan et al., 2021).

5. Managerial implications

This research contributes by examining the importance of important SCI elements in green innovation, resulting in a better understanding of GI implementation. According to some sources, SCI and GI research is still in its early stages. This publication might serve as a useful resource for scholars on this topic. In addition, Jordan's industrial supply chains are yet in the early stages of growth and have significant environmental consequences. As a result, to accommodate the aspects that improve the existing environmental condition, GI should be pushed aggressively. The practical significance of these findings stems from greater knowledge of how outer integration might help green innovation. The current study's findings show that integrating the supply chain with its many partners has a significant impact on the process of building organizational knowledge and, as a result, increases both (GPDI & GPRI). To foster green innovation, companies should seek to adopt external integration, using the capabilities and expertise of their suppliers and customers. Managers' awareness of outer integration is a step forward since establishing outer integration is a complex and difficult issue for managers, so they must collaborate with their supply chain partners from a holistic perspective while developing environmentally friendly products. The firm can also involve its most important customers, soliciting their opinions on product requirements and involving them in the development and creation of green products by providing their first designs and transforming these concepts into green products that meet their needs. Exogenous integration is required to cope with a significant level of uncertainty, according to this study, which provides managers with hypotheses and supporting evidence. Managers today recognize the relevance of both customer-supplier synergies in promoting green product creation in the face of high unpredictability. This means that to support green innovation, managers should concentrate on investing in external integration, because this performance is dependent on information obtained from customer and supplier integration, especially in the face of uncertainty.

6. Limitations and future research

The data for this study was gathered from industrial enterprises in Jordan only once. Longitudinal or multi-source data could be used in future studies to improve the accuracy of the results. Our findings reveal the degree of connection among the hypothesized variables in Jordan, limiting the conclusions' generalizability. More study is needed to confirm these links across cultures and to distinguish between developed and emerging market economies. GI appears to be an essential method for reducing negative environmental effects; however, other characteristics such as market direction, CEO leadership, and environmental management procedures may boost or limit GI that has yet to be investigated. As a result, future research should look into if and how other elements affect green innovation. Even though the outcomes of our investigation were supported by the literature. As a result, research into the impact of SCI innovation in various industries, such as the service sector, can be conducted. Other studies can be undertaken that take into consideration other controlling variables such as industry type, corporate ownership, and ISO 14001 certification, as well as the size and age of the organization. Other studies that take into account adjusted variables such as internal integration, knowledge management, and green technology can also be done.

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