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Green Intellectual Capital and Green Supply Chain Performance: Does Big Data Analytics Capabilities Matter?

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Abstract: In light of global environmental concerns growing, environmental awareness within firms has become more important than before, and many scholars and researchers have argued the importance of environmental management in promoting sustainable organizational performance, especially in the context of supply chains. Thus, the current study aimed at identifying the impact of the components of green intellectual capital (green human capital, green structural capital, green relational capital) on green supply chain performance in the manufacturing sector in Jordan, as well as identifying the moderating role of big data analytics capabilities. To achieve this aim, we developed a conceptual model of Structural Equation Modelling-Partial Least squares and tested through the Smart-PLS software on a sample of 438 respondents. Empirical results showed that each of the components of green intellectual capital and big data analytics explains 71.1% of the variance in green supply chain performance and that all components of green intellectual capital have a statistically significant impact on green supply chain performance. The results also revealed that the relationship between green relational capital and green supply chain performance is moderated through big data analytics capabilities. Finally, this study made a theoretical and managerial implications to the supply chain literature and industry.

Keywords: green intellectual capital; big data analytics capabilities; green supply chain performance; sustainability

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1. Introduction

Because of the changes taking place in the local and global markets and business environment, the increase in competitiveness, globalization and various and numerous disturbances presented major challenges for firms and organizations [1]. In order to overcome these challenges, international and global firms have increased their interest in improving their organizational capabilities to create new competitive advantages and to thereby make them superior to their competitors.

Despite the importance of acquiring competitive advantages in a turbulent environment [2], the means to acquire this advantage have become more difficult [3] for several reasons. This includes financial crises and global health crises such as the COVID-19 pandemic [4]. In turn, the COVID-19 pandemic's disturbances have increased scholarly interest in the sources of excellence and innovation [5,6]. The COVID-19 pandemic has also changed the life and the business scene in every country [7–9], which has resulted in creating innovative and ambitious atmospheres, and significant disruptions in the business environment [10,11].

Among the business aspects, supply chains have been one of the most affected during the COVID-19 pandemic [4]. Repeated closures and precautionary measures by countries have disrupted and interrupted supply chains [12] and caused the loss of competitive value for business organizations. Ref. [13] similarly indicated that supply chains, around the globe, were negatively and significantly affected from the beginning of the COVID-19 pandemic because the precautionary measures taken by the governments of various countries disrupted supply chains, which, according to [14], led to a failure in global trade and affected multinational and national firms alike. This outcome, in turn, has led to a reduction in firms' profits and a major decrease in their performance levels [15].

In addition, managers, officials and public policymakers have been affected by the challenges induced by the COVID-19 pandemic. The decisions concerning the sustainability issues of supply chains and the supply-and-demand balance in the global markets [16,17] had high uncertainty. However, some challenges such as the environmental challenges have been heavily concerned and severely neglected for a long time [18].

In the last few decades, several business and managerial studies have highlighted the importance of focusing on activities directed at preserving the environment [19]. These studies have confirmed that the success of organizations and firms depends on their external environment and its cleanliness and safety. Ref. [20] asserted that the environmental aspect is, therefore, no longer a luxury for firms, but a strategic and competitive necessity to create competitive advantages.

According to the Resource-Based View (RBV) theory, and in order to create a sustainable competitive advantage, firms and organizations can use the outcomes of their various resources and combine these resources with different activities to generate an added value to their products and services [2]. On the basis of RBV, several scholars (see [21,22]) posit that firms' interest in the surrounding external environment maximizes their use of natural resources and reduces waste. This, accordingly, can lead those firms to achieve a competitive advantage, and reach the Natural Resource-Based View (NRBV).

Indeed, supply chain sustainability is one of the important aspects of creating added value for customers [23]. The supply chain is a group or network of interconnected relationships that aim to increase profitability and create added value for customers. Firms' interest in the flow of products and services from production to customers leads to customer satisfaction and creates a competitive advantage [24]. With the current environmental turmoil worldwide, firms' interest in promoting environmental initiatives in the supply chain will improve their optimal use of resources, increase efficiency, and reduce waste [3]. Consequently, this will help the firms in achieving economic, social, and environmental sustainability [25], and it will assist them in attaining environmental responsibility, which has become a strategic orientation for international firms to improve their brand image. This will also shed the lights on the organizational and moral pressures on these firms to address them and become more oriented towards environmental responsibility and green business aspects, such as green supply chain [26,27].

Ref. [28] defined green supply chain management as the managerial activities that focuses on the traditional aspects of the supply chain with greater attention to environmental issues. The use of the organizational capabilities towards a green environment fosters and enhances the growth of the green supply chain [29]. The success of environmental initiatives in the supply chain can be measured by several indicators, such as (a) including providing environment-friendly products and services, (b) adding new and innovative methods of packaging and designing processes oriented towards the environment, or (c) reducing the waste of energy and natural resources in the supply chain [30–32]. This requires linking the intellectual capabilities and knowledge-based resources to supply chain activities.

Previous literature has focused on the essential and positive role that intellectual capital plays in enhancing sources for building sustainable competitive advantages and improving organizational performance in general [33,34]. With the importance of intellectual capital as one of the antecedents for improving performance, several previous studies have focused on the positive relationship between intellectual capital and supply chain performance [35–38]. Firms' exploitation of their human resource knowledge and skills and the optimal use of their intellectual capital enhances their ability to innovate. This innovation can lead to the creation of new ways to improve the supply chain and, consequently, improve the performance of the chain and add value for customers.

From an environmental management perspective, green intellectual capital is described as the sum of existing knowledge and skills, which are used within the firm in organizational and environment-oriented processes and activities, and which give the firm a competitive advantage [39,40]. The knowledge-based view theory posits that green intellectual capital contributes to the knowledge and experiences sharing process among individuals within a firm, as well as to the knowledge sharing practices at the organizational level. This should also facilitate the environmental knowledge and skills sharing practices required to achieve a sustainable performance [40,41].

Therefore, firms' exploitation of their intellectual capital oriented towards environmental initiatives improves the performance of the green supply chain by providing new knowledge and skill contributions that are used to improve the performance of the green supply chain [35,42,43]. Firms' use of their information resources and management of information flow among supply chains enhances organizational capability to face operational risks and increases the speed of firms' responses to various environmental changes [44], thereby enhancing green supply chain performance [45,46].

Several empirical studies have confirmed that firms' use of Fourth Industrial Revolution technologies, such as big data analytics, artificial intelligence, and cloud computing, can create new opportunities for the growth of emerging economies [47,48]. These technologies have helped firms improve their competitiveness, which is positively reflected in their organizational and innovation performance [49,50].

Indeed, Big Data analytics provide new and different insights on improving the performance of supply chains [51–54]. Specifically, big data analytics can be used to improve decision-making and solve various problems that may arise in supply chain channels [55] as well as improve supply chain performance, because the supply chain is highly dependent on information [56]. In addition, big data analytics can provide firms with greater control over the supply chain and reduce risks and disruptions from external causes. According to [57], firms' use of big data analytics in supply chain management improves the performance level of the chain, leading to a competitive advantage.

With the importance of big data analytics capabilities in improving supply chain performance, numerous studies have addressed the huge potential in big data's use in environmental initiatives and trends [58]. Big data analytics contribute to providing statistical and mathematical models such as predictive models that can be used to discover new patterns that contribute to increasing general and environmental innovations [59,60]. Additionally, it can contribute to the improvement of organizational activities and to the increase of the efficiency of processes, leading to reducing waste in the supply chain [61–63] to many organizations in several industries, mainly the industrial sector to many developed and developing countries.

The industrial sector is one of the main economic sectors in a developing country such as Jordan [64,65]. This sector has witnessed noticeable increase in growth, particularly in the past few years, because this sector comprises several firms characterized by a high knowledge density that uses advanced technology [66]. Jordan is one of the developing countries that focus on sustainable development by encouraging firms to reduce transportation and energy expenses, and to use contemporary technologies that focus on solar energy and its applications.

Overall, this study aimed to answer two research questions (RQ):

RQ1. What is the effect of green intellectual capital (green human capital, green structural capital, and green relational capital) on green supply chain performance in the manufacturing sector in Jordan?

RQ2. Do big data analytics capabilities have a moderator role in the relationship between green intellectual capital (green human capital, green structural capital, and green relational capital) and green supply chain performance in the manufacturing sector in Jordan?

In order to address these research questions, the research approach was designed to yield a conceptual model that illustrates the effects of the relationship between the green intellectual capital (through its three components: green human capita, structural capital, and relational capital) and the big data analytics (as a moderating role) on the green supply chain performance.

The research model is considered genuine and contributes to the relevant literature by providing a better understanding about the predictors that explain the green supply chain performance, and exploring the moderating role of the big data analytics capabilities in the relationship between the green intellectual capital dimensions and the green supply chain performance. Additionally, this research is considered genuine as it is the first study to test and validate the research model in a vital industry in one developing country: Jordan.

The remainder of this manuscript is organized as follows: Section 2 reviews the theoretical framework and hypotheses development; Section 3 presents the methodology; Section 4 presents data analysis and results; and Section 5 presents the discussion and conclusion.

2. Theoretical Framework and Hypotheses Development

2.1. Intellectual Capital and Green Supply Chain Performance

2.1.1. Green Human Capital and Green Supply Chain Performance

The green supply chain is a modern trend to reduce environmental risks and waste in the supply chain [67,68]. It is a concept that focuses on integrating environmental dimensions and aspects as well as the traditional dimensions and aspects of the supply chain [57]. The green supply chain focuses on assessing the environmental effects of products at all stages of production up to the final customer [69]. Firms' tendency to use environmental management in supply chain activities leads to stopping waste and increasing efficiency along the supply chain [70], thereby increasing the level of sustainable performance [71]. Refs. [72,73] emphasized that the green supply chain can add new value to the supply chain by increasing the use of environment-friendly green systems and also integrating technology to mitigate the effects of harmful traditional systems on the environment, leading to improved operational activities, reduced operational costs [74] and an improved reputation for firms [75].

Several metrics have been proposed to measure the green supply chain performance [76]. The green supply chain performance can be measured by the extent to which they reduce negative environmental impacts such as air and water pollution [77–79]. The green supply chain performance can also be measured by the extent to which they better exploit resources and thereby reduce waste [80].

Green supply chains improve firms' sustainable performance and improve the efficiency of activities and processes in these firms [45]. However, green supply chains can improve firms' responses to markets and develop new products and services [81] as well as increase the application level of social responsibility in these companies, leading to the improvement of firms' reputation in the long run [82].

To ensure the success of managing green supply chains and improving the environmental performance of firms, several studies in the supply chain management literature, such as [83–85], have emphasized the importance of integration within these chains, such as green integration with customers, which is described as environmental cooperation and the sharing of information related to environmental aspects with key customers to improve green practices within the supply chain [83], as well as integration with suppliers, which focuses on building long-term cooperative partnerships between the firm and key suppliers, particularly strategic coordination concerning environmental initiatives and activities and taking joint decisions related to environmental aspects [86]. Green internal integration, the main pillar for the success of the green supply chain, focuses on coordinating the organizational efforts undertaken by the senior management and sharing these efforts with all organizational units and departments that focus on planning and implementing environmental programs in the supply chain [87,88].

Several studies have confirmed a close relationship between green human capital and increased performance of green supply chains [89,90] as well as improved sustainable performance [91]. From the traditional point of view, human capital can be described as the sum of the skills, knowledge, and abilities that individuals possess within a company [92]. From an NRBV point of view, green human capital refers to the accumulated experiences of employees and their skills, knowledge, and capabilities related to environmental aspects or environmental protection and environmental awareness [93]. Although human capital is difficult to maintain because of the inability to store existing ideas in the minds of employees, this resource can achieve unique competitive advantages for firms by generating new ideas and innovation [33,94]. Therefore, intellectual capital is one of the determinants and antecedents of organizational success and improved levels of performance [95,96]. From this point of view, [97,98] emphasized the importance of green human capital as a basic resource for firms, enabling them to implement green supply chain management practices.

Refs. [99–101] discussed the importance of green human capital as one of the key factors for green supply chain success. Green human capital can provide basic knowledge and skills to overcome environmental problems [91], leading to improved efficiency of processes [102]. Moreover, green human capital can foster new ideas and provide unique environmental innovations that have not previously existed and that can improve the green supply chain performance [103].

Ref. [67] posited that the support of human resources plays a key role in the development of environment-friendly products, enhancing the importance of human capital oriented towards the environment—more specifically, to improve and support environmental and green initiatives in firms. Several studies have indicated that green human capital is more receptive to training and learning regarding environmental aspects, which improves the efficiency of green supply chain performance by developing employees' capabilities to address environmental risks [104,105].

From the previous discussion, the following hypothesis can be made:

H1. *Green human capital positively affects green supply chain performance.*

2.1.2. Green Structural Capital and Green Supply Chain Performance

Structural capital refers to the organizational capabilities that firms own that transform the ideas and innovation of staff into tangible and realistic assets that can be referred to at any time and used and exploited within these firms [106,107]. Structural capital can also be described as the product of acquired knowledge that the firm has acquired through daily activities and knowledge exchange among employees of the firm or through aspects of its external environment such as customers or suppliers [108]. Structural capital generally consists of a set of procedures, policies, patents, knowledge bases, and data [109]. These components help human capital provide solutions to problems with which the firm is confronted [42,110].

Green structural capital is a set of organizational capabilities of systems, procedures, databases, and patents in the context of environmental protection and green orientation that the firm owns [111,112]. Green structural capital enables environmental protection initiatives by providing supporting infrastructure for these initiatives [101,113]. Furthermore, green structural capital can assist the efforts of top management in creating an environmentally oriented organizational culture [114] as well as guide employees to best environmental practices and support and direct environmental programs [111].

Firms' orientation towards social responsibility practices and attention to environmental issues plays a key role in improving the level of green structural capital [90]. The focus of senior management on green orientation makes these firms more interested in transferring the experiences and knowledge of employees, which represent green human capital, into routine internal knowledge [115,116] used for green programs and initiatives.

Several studies have confirmed that green structural capital is positively associated with enhancing sustainable business performance [117] as well as creating competitive advantages [118]. In the context of supply chains, green structural capital can enhance green supply chain performance by supporting knowledge exchange among employees, firms, and suppliers to achieve success in environmental initiatives [42]. Green structural capital can further help firms exploit their technological and knowledge capabilities to achieve environmentally oriented organizational goals and thus achieve high performance in the supply chain concerning preserving the environment [35,40,41]. Despite the importance of structural capital and its effective role in achieving sustainable performance in the supply chain, several studies have confirmed that green structural capital can improve green internal integration in the supply chain by integrating organizational knowledge and technology capabilities within the supply chain leading to better performance results [36]. To improve the green supply chain performance, it is important to focus on and develop strategic relationships with key suppliers and customers [119].

From the previous discussion, the following hypothesis can be assumed:

H2. *Green structural capital positively affects green supply chain performance.*

2.1.3. Green Relational Capital and Green Supply Chain Performance

Through the network of relationships that they own, firms can create added value and a competitive advantage over competitors [110]. Relational capital refers to the firm's ability to interact with its surroundings and with key stakeholders [108]. These relationships are represented by the value obtained from within or outside the firm, collectively or individually [120]. Relational capital contributes to access a diverse network of resources, knowledge, and experiences through its exchange with collaborating parties [121], creating value for the firm's customers by increasing the delivery of new products and services [122].

In the environmental context and in environmental preservation, green relational capital refers to the firm's relationships with the main stakeholders on environmental aspects and environmental management that contribute to the firm's competitive advantage [123]. Green relational capital provides information about the firm's social responsibility and its progress in implementing its environmental plans [124], building trust between the firm and its main stakeholders [33]. It is also possible for the firm to benefit from green relational capital through increasing organizational and individual learning capabilities [111], which increases the knowledge within the firm and thus leads to new green innovations [125].

Several studies in the literature have confirmed that there is a positive relationship between green relational capital and green supply chain performance. Ref. [126] explained that firms' development of their green relational capital leads to a wide sharing of environmental information between suppliers and stakeholders with firms and thus reduces waste and increases efficiency. Ref. [127] additionally discussed the importance of green relational capital in building strategic relationships with stakeholders based on respecting the environment and supporting green manufacturing and environmental strategies at all stages of the supply chain [128].

Firms that focus on building strategic relationships based on environmental considerations can increase cooperation in quality management, leading to more efficient products and increasing supply chain performance by reducing operational costs in the supply chain [126]. According to the social capital theory, one of the basic requirements for supply chain success is to establish long-term cooperative relationships among the firm, suppliers and all cooperating parties [31]. Thus, green relational capital enhances cooperation in the green supply chain, leading to increased performance [128]. Ref. [129] emphasized that cooperation in the green supply chain improves response to environmental and operational risks as well as knowledge sharing among all these parties.

From the previous discussion, the following hypothesis can be assumed:

H3. *Green relational capital positively affects green supply chain performance.*

2.2. The Moderating Role of Big Data Analytics Capabilities

Big data analytics refers to modern technical tools that provide the ability to manage and process data of a large and diverse size [130]. Big data analytics focuses on processing big data, which can provide new knowledge and can be used and exploited to reach innovations or find solutions to various problems [131–133]. Big data analytics aims to make a difference in the current business scene [134] by reaching a greater understanding of the hidden patterns within this data to achieve firms' competitive advantages [135,136].

Scholars and practitioners have given particular attention to the possibilities that big data analytics provides for organizations and firms [137]. Ref. [138] confirmed that big data analytics is still in the early stages of examining firms' exploitation of these capabilities. In the context of supply chain management, big data analytics can provide lower operational costs, increase supply chain agility, and improve customer satisfaction [139]. These analytics can provide organizational capabilities that help firms anticipate demand and supply more accurately [140] as well as develop the best predictive models for the supply chain to achieve agility in the supply chain [52,141,142].

Several empirical studies have discussed the role of big data analytics within the supply chain. The use of big data analytics enhances the improvement of operations and manufacturing efficiency to achieve better performance within the supply chain [143], thereby creating new value for customers [144]. Big data analytics also reduces the product development and manufacturing cycle, leading to reduced waste in the manufacturing processes [145]. Ref. [19] expressed the importance of big data analytics because of its many new technologies and techniques designed to create economic value from large data by providing new ways to access knowledge, discover, and seize opportunities.

According to [146,147], supply chain management makes use of big data analytics techniques to better understand what is going on and to thus facilitate decision-making in the supply chain as well as to provide better predictions about market trends and customer preferences leading to reducing costs. Furthermore, big data analytics provides real-time supply chain management, which provides the firm with quick ways to make decisions and significantly lower risk ratios [54,148]. Because the relationship between big data analytics and supply chain management is clear, several scholars have called this relationship the concept of supply chain analytics [149], which focuses on using the organizational capabilities that firms own to exploit big data to improve the efficiency of activities [54].

Although the literature concerning supply chain management has proven the importance of big data analytics capabilities in improving supply chain performance [150], empirical research that has examined the positive relationship between big data analytics and green supply chain management is still relatively scarce [151]. Although the emergence of Fourth Industrial Revolution technologies has provided an opportunity to exploit these technologies to improve supply chain performance, there is an important opportunity to use these technologies to improve sustainable performance in the supply chain [152]. Big data analytics can be used to improve levels of sustainability through the design of environment-friendly products [153] or the development of decision support systems to aid decision-making when environmental risks arise [154].

Big data analytics can boost green supply chain performance by exploiting data from different external sources that create new opportunities for collaboration with suppliers and key stakeholders in the environment-related decision-making process [61]. In addition, big data analytics can enhance internal cooperation within the supply chain by sharing information extracted from this data in real-time, which improves the efficiency of internal processes and activities [155]. Big data analytics can also provide predictive modeling and simulation techniques that improve the company's processing capabilities and thus improve the internal green supply chain performance by moving towards improving green internal processes, such as logistics, warehousing, and supplies within the firm [149]. Ref. [156] emphasized that big data analytics is useful with regard to reducing the negative effects of environmental disasters, which may significantly affect public health, thereby alleviating disruptions in the green supply chain. Integrating the big data analytics capabilities into the green supply chain reduces the critical consequences of operational or environmental risks that may harm the surrounding environment [157], thus improving environmental and sustainable performance [158].

Based on the previous discussion, the following hypotheses can be assumed:

H4. *Big data analytics moderates the relationship between green human capital and green supply chain performance.*

H5. *Big data analytics moderates the relationship between green structural capital and green supply chain performance.*

H6. *Big data analytics moderates the relationship between green relational capital and green supply chain performance.*

Figure 1 shows the hypothetical study model that examines the causal relationships between exogenous and endogenous constructs.

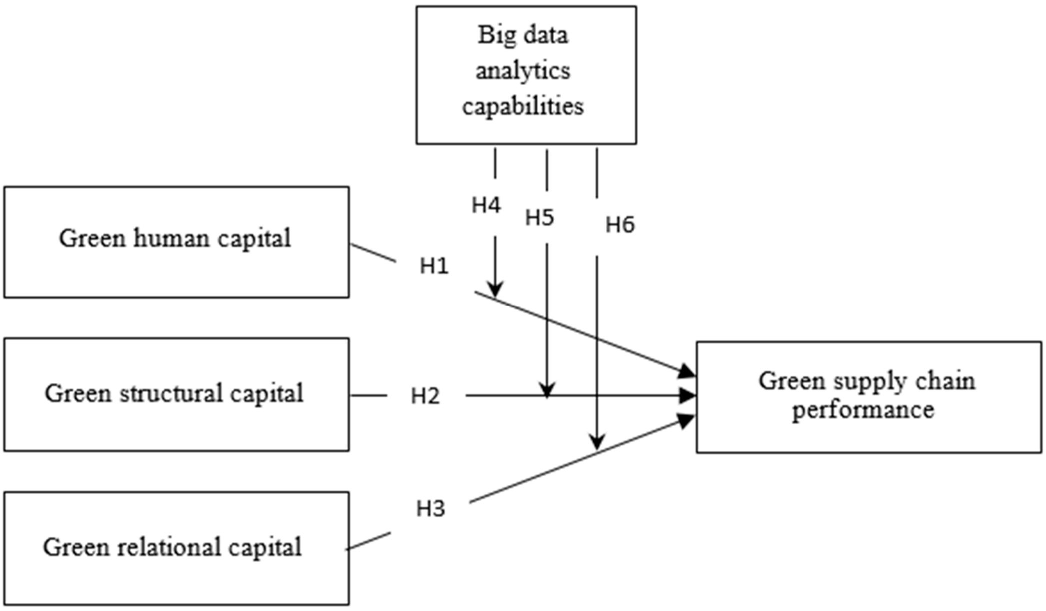

Figure 1. Study framework model.

3. Methodology

This study examined the causal relationships between green intellectual capital (green human capital, green structural capital, and relational green capital) on green supply chain performance in the manufacturing sector in Jordan and the moderating role of big data analytics capabilities. To achieve the study's objectives, the quantitative-deductive causal method was used, which focuses on testing hypotheses and causal relationships [159]. This approach allows for testing the relationships between different constructs statistically so that it provides an empirical understanding of the relationships between the constructs [160]. To collect the study data, cross-sectional data was used by distributing the questionnaire to the study sample, and, therefore, the data was collected at one point.

3.1. Measures and Instruments

To test the casual relationships between exogenous constructs and endogenous constructs, a scale (questionnaire) was developed by adapting the adopted scales from the published literature on the study constructs. The questionnaire was presented to a group of academic specialists in supply chain management and business analytics, and the scale was modified according to their observations. The scale was then translated from English to the local language (Arabic) in Jordan to make it accessible to the highest possible number of participants. The questionnaire items were developed with a five-point Likert scale to measure the participants' responses to the questionnaire items.

The last version of the questionnaire included four sections: (1) demographic information about the participant; (2) construct items related to green intellectual capital, adopted by the studies of [89–91,161]; (3) construct items related to big data analytics capabilities, adopted from the studies of [33,58,162–164]; and (4) construct items related to green supply chain performance, adopted from the studies of [80,90,165]. Table 1 shows the questionnaire items distributed to the study participants.

Table 1. Construct Measurements.

Construct	Item Code	Item	References
Green Human Capital	GHC1	The firm's employees have sufficient functional and scientific skills related to environmental protection.	[90,91,112,161]
	GHC2	The firm is constantly training employees to provide them with new environmental skills and knowledge.	
	GHC3	The firm's employees have good environmental service performance.	
	GHC4	The firm's employees work as a team when carrying out environmental work and activities within the firm.	
	GHC5	The firm's employees are considered environmentally better compared to competitors from other firms.	
Green Structural Capital	GSC1	The firm has an advanced management system to protect the environment.	[90,91,112,161]
	GSC2	The firm is constantly spending on environmentally friendly facilities.	
	GSC3	The firm has efficient processes that achieve resource savings, leading to environmental protection.	
	GSC4	The firm applies knowledge management systems to share environmental knowledge among employees.	
	GSC5	The firm documents the environmental knowledge and experience of employees through databases.	
	GSC6	The firm documents intellectual property rights related to the environment (such as patents and software) as a way to store knowledge.	
Green Relational Capital	GRC1	The firm takes into consideration the environmental aspects of its customers when designing or manufacturing its products.	[90,91,112,161]
	GRC2	Customers feel satisfied when the firm offers products of an environmentally friendly nature.	
	GRC3	The firm has long-term, environmentally focused, collaborative relationships with suppliers.	
	GRC4	The firm has long-term, environmentally focused, collaborative relationships with customers.	
	GRC5	The firm actively cooperates with external parties to develop new environmental innovations or improve environmentally friendly ways of working.	
Big Data Analytics Capabilities	BDAC1	The firm continuously invests in big data analysis software.	[33,58,162–164]
	BDAC2	The firm invests in technical infrastructure that includes information integration using advanced technology.	
	BDAC3	The firm invests in processes that ensure the availability of high-quality and timely data.	
	BDAC4	The firm's management attracts human resources with knowledge and experience in big data analytics.	
	BDAC5	The firm encourages employees to make use of their skills in big data analysis to solve various problems in creative ways.	
	BDAC6	The firm has administrative and organizational resources to take relevant actions on insights derived from big data analytics.	
Green Supply Chain Performance	GSCP1	The firm's manufacturing system is energy-saving.	[80,90,165]
	GSCP2	The firm's management encourages suppliers to improve environmentally oriented transportation processes continuously.	
	GSCP3	The firm's management provides continuous support and training to suppliers concerning environmental aspects and considerations.	
	GSCP4	The firm's management is interested in enhancing the communication level with its main customers and providing them with the firm's latest environmental developments.	
	GSCP5	The stock level has decreased over the past period.	
	GSCP6	The cost of purchasing materials has decreased over the past period.	

3.2. The Study Population and Sample

This study was conducted in the manufacturing sector in Jordan. This sector was chosen for several reasons, the most important of which is the effect of the global COVID-19 pandemic on global supply chains [4], which has constituted a widespread disturbance in the sustainability of supply chains; thus, this study aims to understand the strategies that firms in this sector can adopt to address the pandemic by achieving sustainability in the supply chain, in particular the green supply chain. The simple random sampling technique was adopted in the distribution of the questionnaire because this method provides equivalence and equality in the selection of the study sample [160,166], thus avoiding bias in the distribution process. The managers of Jordanian manufacturing firms were approached to ensure the correct use of the simple random sampling method. A sampling frame for the workers in these firms was included in order to ensure the use of randomness in the study.

The analysis unit included all the organizational and administrative units within these firms. The number of distributed questionnaires adopted for statistical analysis was 438. The questionnaire survey was distributed in the first quarter of the year 2022. Table 2 shows the distribution of participants by demographic and personal characteristics.

Table 2. Distribution of Respondents.

Characteristics	Category	No.	%
Gender	Males	253	57.8%
	Females	185	42.2%
Academic Qualification	Diploma or Less	109	24.9%
	Bachelor's Degree	282	64.4%
	Postgraduate Degree	47	10.7%
Job in Company	Manager/Head of Department	39	8.90%
	Administrative Employee	137	31.3%
	Nonadministrative Employee	262	59.8%
Total		438	100

The common method variance (CMV) problem has been verified, as this is a common problem when using self-administered questionnaires, especially questionnaires [167]. The common method variance (CMV) problem refers to "a variance that is attributable to the measurement method rather than to the construct of interest" [168] (p. 879).

This problem is clearly formed when collecting data about different study variables at the same time [167], and thus this problem can produce misleading results, especially in increasing the relationships between variables in an unjustified way [169] (p. 325).

To detect this problem, Harman's single-factor test was performed in the SPSS program, where there must be one factor for all questionnaire items, and the variance value must be less than 50% [167].

According to the results of Harman's single-factor test, the variance value is (44.43%), which means that there are no concerns about the CMV problem.

4. Data Analysis and Results

This study aimed to investigate the causal relationships among several constructs because it contains several direct-influencing hypotheses, mediating hypotheses, and moderating hypotheses. Because of the mechanism of empirically implementing the model, Structural Equation Modeling Partial Least Squares (SEM-PLS) was used by the Smart-PLS V.3 Program, which is considered one of the techniques that provides flexibility in handling causal and simultaneous relationships models [170]. SEM-PLS provides greater flexibility through the bootstrapping technique and estimation methods, does not require a large sample size or normal distribution of data [171], and can be used in new and exploratory studies [172]. When using SEM-PLS, the following must be ensured: (a) the measurement model, which is also called the outer model (validity and reliability); and (b) the relationships and hypotheses are tested through the structural model, or the inner model [173].

4.1. The Measurement Model

Before conducting the inner model examination, validity tests were conducted by convergent validity and discriminant validity in all exogenous and endogenous constructs. The convergent validity was tested by calculating the average variance extracted (AVE) values that have achieved a statistically required level greater than 0.50 and factor loadings that have reached values greater than or equal to 0.70, as recommended by [171,173,174]. Internal consistency validity was also confirmed and statistically accepted through the values of the alpha Cronbach coefficients and composite reliability so that all values were greater than 0.70. To improve the quality of convergent validity, items with factor loadings lower than 0.70 were excluded because the presence of these items would lead to lower AVE values and thus violate the conditions for convergent validity. Therefore, GHC2, GHC5, GSC1, GSC2, GSC5, GRC5, and BDAC6 were excluded. Table 3 summarizes the convergent validity and reliability of the constructs.

Table 3. Convergent Validity and Reliability of Constructs.

Construct	Item	Factor Loading	AVE	Composite Reliability	Cronbach's Alpha
Green Human Capital	GHC1	0.883	0.804	0.925	0.878
	GHC2 *	-			
	GHC3	0.910			
	GHC4	0.897			
	GHC5 *	-			
Green Structural Capital	GSC1 *	-	0.802	0.924	0.877
	GSC2 *	-			
	GSC3	0.892			
	GSC4 *	-			
	GSC5	0.885			
	GSC6	0.910			
Green Relational Capital	GRC1	0.808	0.664	0.888	0.832
	GRC2	0.811			
	GRC3	0.849			
	GRC4	0.790			
	GRC5 *	-			
Big Data Analytics Capabilities	BDAC1	0.820	0.670	0.910	0.876
	BDAC2	0.782			
	BDAC3	0.855			
	BDAC4	0.781			
	BDAC5	0.850			
	BDAC6 *	-			
Green Supply Chain Performance	GSCP1	0.686	0.712	0.936	0.917
	GSCP2	0.859			
	GSCP3	0.862			
	GSCP4	0.890			
	GSCP5	0.885			
	GSCP6	0.864			

* Removed item.

Ref. [174] averred that to verify the outer model, it must be ensured that the discriminant validity test is achieved in all constructs in the study model using [171] method, which is a common method for assessing discriminant validity [175]. Based on this method, the square root values of the AVE of the construct must be greater than the values of the correlation coefficients between the construct and the other constructs. According to Table 4, the square root values of the AVE of all constructs were greater than the correlation coefficients among other constructs, which indicates statistically acceptable discriminant validity.

4.2. Structural Model

This study includes six hypotheses—three direct-influencing hypotheses and three hypotheses that test the moderating role of big data analytics capabilities. The relationships between exogenous constructs and endogenous constructs were tested by the bootstrapping technique, which is a nonparametric technique provided by Smart-PLS [176].

Table 4. Discriminant Validity (Fornell–Larcker).

No	Construct	1	2	3	4	5
1	Big Data Analytics Capabilities	**0.818**				
2	Green Human Capital	0.684	**0.897**			
3	Green Structural Capital	0.737	0.697	**0.896**		
4	Green Relational Capital	0.733	0.758	0.699	**0.815**	
5	Green Supply Chain Performance	0.737	0.744	0.732	0.775	**0.844**

Note. The bolded values clarify the square root of the AVE.

The results of the inner model test are summarized in Figure 2. The figure shows estimates of paths and causal relationships between the components of green intellectual capital (green human capital, green structural capital, and green relational capital) and the green supply chain performance with the presence of big data analytics capabilities as a moderating construct. The values of the path coefficients (β) as well as calculated t values and p values were used to evaluate the relationships between exogenous and endogenous constructs. A rule of thumb by which the hypothesis is accepted is that the calculated t value must be greater than 1.96 and the p value must be less than 0.05, and if the result is otherwise, the null hypothesis is accepted.

Table 5 shows the results of hypotheses testing. The results supported the proposed study hypotheses (H1, H2, and H3) related to the direct effect of the components of green intellectual capital on green supply chain performance. All direct relationships were positive and statistically significant. The results of the H1 test, which explain the direct effect of green human capital on the green supply chain performance were $\beta = 0.207$, $t = 3.620$ and $p = 0.000$. The results of the H2 test, which explain the direct effect of green structural capital on the green supply chain performance were $\beta = 193$, $t = 3.931$ and $p = 0.000$), and the results of the H3 test, which explains the direct effect of green relational capital on the green supply chain performance, were $\beta = 0.339$, $t = 6.385$ and $p = 0.000$.

The study hypothesis related to the moderating role of big data analytics capabilities in the relationship between the components of green intellectual capital and green supply chain performance were tested. The results showed that H6 was supported, but H4 and H5 were not supported because they did not have statistical significance because the p value was greater than 0.05. The effect of big data analytics capabilities on green supply chain performance was positive and statistically significant ($\beta = 230$, $t = 4.102$, $p = 0.000$). The result of the H4 test, which explains the moderating effect of the interaction of green human capital with big data analytics capabilities (GHC × BDA), was not statistically significant ($\beta = -0.05$, $t = 0.962$, $p = 0.336$). The result of the H5 test, which explains the moderating effect of the interaction of green structural capital with big data analytics capabilities (GSC × BDA), was not statistically significant ($\beta = 0.014$, $t = 0.273$, $p = 0.785$). Furthermore, the result of the H6 test, which explains the moderating effect of the interaction of green relational capital with big data analytics capabilities (GRC × BDA), was positive and statistically significant ($\beta = 0.092$, $t = 2.207$,

p = 0.027). Figure 3 shows that big data analytics capabilities improve the relationship between green relational capital and green supply chain performance. The value of R^2 was calculated as 0.717, which indicates a high explanation percent of the model and that the model has a high explanation quality [174]; therefore, the value of the variance in endogenous constructs was 71.7%.

Table 5. Results of Testing the Study Hypotheses.

Path	Path Coefficient (β)	Std Error	*T* Statistic	*p* Value	Result
GHC ⇒ GSCP	0.207	0.057	3.620	0.000	Supported
GSC ⇒ GSCP	0.193	0.049	3.931	0.000	Supported
GRC ⇒ GSCP	0.339	0.053	6.385	0.000	Supported
BDAC ⇒ GSCP	0.230	0.056	4.102	0.000	Supported
GHC × BDAC ⇒ GSCP	−0.05	0.052	0.962	0.336	Not Supported
GSC × BDAC ⇒ GSCP	0.014	0.050	0.273	0.785	Not Supported
GRC × BDAC ⇒ GSCP	0.092	0.042	2.207	0.027	Supported

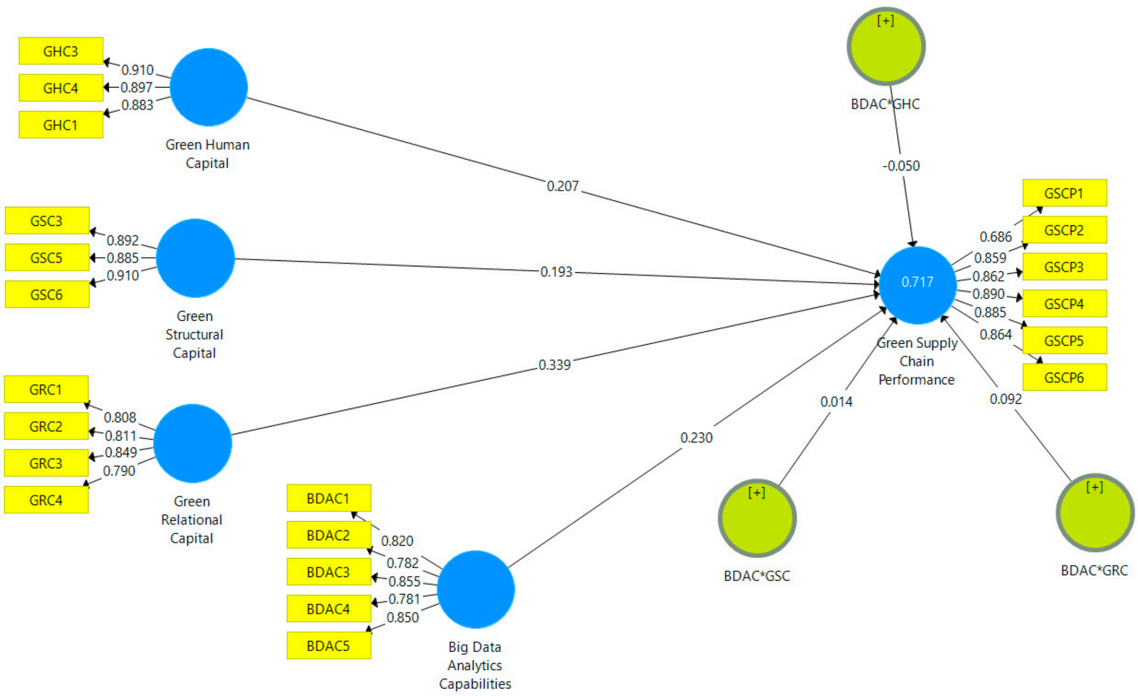

Figure 2. Structural equation modelling for study model.

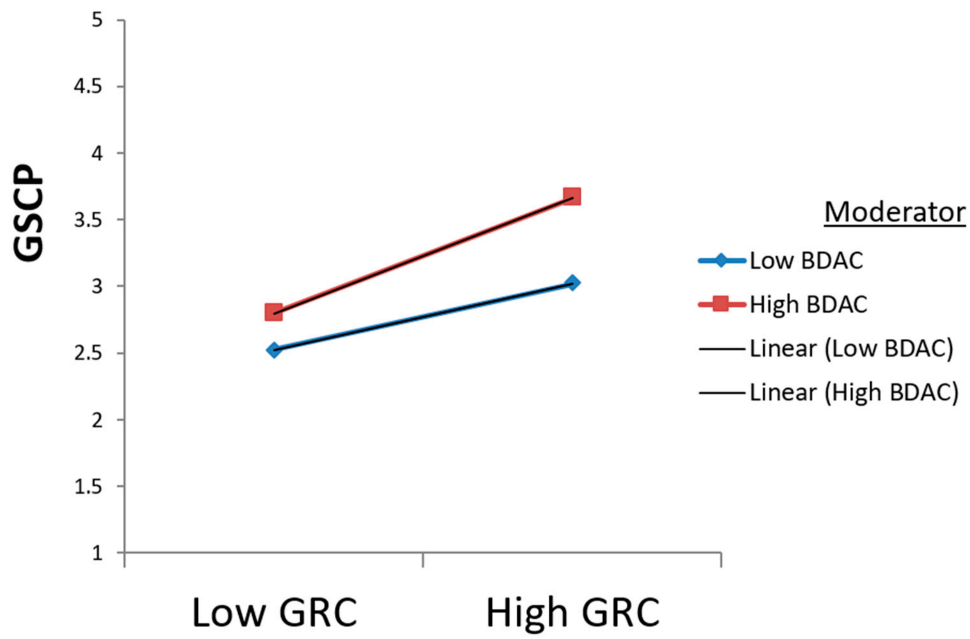

Figure 3. Big data analytics moderates the relationship between green relational capital and green supply chain performance.

5. Discussion and Conclusions

The current study tested the causal relationships between green intellectual capital and green supply chain performance based on the presence of big data analytics capabilities as a moderating variable in the manufacturing sector in Jordan. The manufacturing sector in Jordan, which is the second largest sector in the Jordanian economy after the services sector [65], is considered one of the most important sectors in the Jordanian economy.

The study found several empirical results through the data collected from employees in the Jordanian manufacturing sector. All the direct hypotheses examining the effect of green intellectual capital on the green supply chain performance were accepted, and the effect of big data analytics capabilities on the green supply chain performance was positive. The percent of the variance in the green supply chain performance was 71.1%.

Furthermore, H1, which supports the positive effect of green human capital on the green supply chain performance, was accepted. Previous literature showed the presence of positive relationships between green human capital and green supply chain performance [99–101]. The skills and experience accumulated by employees concerning environmental aspects can improve the efficiency of processes and reduce the resulting environmental risks associated with supply chain activities [102,104]. Green human capital, which is an intangible asset, plays an important role in creating environment-oriented organizational capabilities through learning, training, and exploiting the tacit and existing knowledge of individuals. Firms may be seeking to achieve superior performance in the green supply chain benefit from the expertise of employees in these firms by investing in this asset, thereby leading to the creation of new ideas, skills, and knowledge regarding environmental aspects and thus solving environmental issues facing the supply chain [67].

H2, which supports a significant and positive relationship of green structural capital on the green supply chain performance, was accepted. Green structural capital enhances the environmental performance of the supply chain in the Jordanian manufacturing sector. The study's results agreed with previous literature, confirming the existence of a causal relationship between green structural capital and green supply chain performance. Previous studies showed that green structural capital helps firms improve environmental management levels [35,40–42] to achieve high performance. In the green supply chain [111], firms with structural capital oriented towards environmental programs improve green supply chain performance through using information systems, knowledge management systems and processes related to the environment that generate new environmental value for manufacturing firms and thus enhance the sustainable performance of these firms [117].

H3 was also accepted, confirming that green relational capital positively enhances the green supply chain performance [126–128]. Green relational capital increases collaboration on environmental aspects by taking advantage of strategic relationships with stakeholders, particularly suppliers and customers [177]. Previous studies have also discussed the need for firms to use their internal and external relationships to share information related to environmental issues [129], and this enhances integration in the green supply chain [178] by providing more efficient products and reducing operational costs in the supply chain [126]. One particularly striking empirical result was that the most influential component of green intellectual capital in the green supply chain performance was green relational capital, indicating that the Jordanian manufacturing sector's interest in strategic internal and external relations with key stakeholders generates a unique added value that improves the green supply chain performance.

The study's results concerning the moderating role of big data analytics capabilities are noteworthy because H6 was accepted, whereas both H4 and H5 were rejected. According to the experimental results, big data analytics capabilities played a moderating and positive role in the relationship between green relational capital and green supply chain performance. According to the RBV, firms' exploitation and incorporation of their unique resources into their activities enhance organizational performance. From an NRBV viewpoint, sustainable performance can be improved through optimal resource utilization, particularly when considering environmental aspects [21]. Thus, the use of industrial firms in Jordan for their green relational capital with big data analytics will enhance the green supply chain performance by collecting big data from key suppliers and customers, generating new knowledge and sharing it within the supply chain to improve the green supply chain performance [61,133,149,179].

With the importance of big data analytics capabilities in improving green supply chain performance [180], the empirical results revealed that there was no moderating role for big data analytics capabilities with green human capital and green structural capital on green supply chain performance. Although previous literature has emphasized the importance of previous relationships and their role in improving the performance of the green supply chain, these results may differ among different contexts because the manufacturing sector in Jordan is considered an emerging sector. Therefore, firms may have medium or low capabilities in adopting big data analytics, or the process of collecting large data needs to be improved in a way that raises the quality level of this data.

6. Implications

6.1. Theoretical Implications

This study has numerous theoretical implications. The main contribution of this study is the development of the conceptual model that investigates the relationships of the green intellectual capital's dimensions and the big data analytics capabilities and the green supply chain performance, in the manufacturing sector in Jordan. Although several studies have examined the relationship of intellectual capital with supply chain performance according to big data analytics, this study is one of the few studies that focused on the environmental aspect of these relationships and the extent to which these firms benefit from big data analytics capabilities.

Based on the RBV and NRBV, the study confirmed what previous studies have shown, which is that focusing on organizational efforts to build strong green intellectual capital enhances supply chain sustainability and improves green supply chain performance. However, this study further highlighted the existence of a clear and significant role for green relational capital in the green supply chain performance. Furthermore, this study provides important results for academics by shedding more light on social capital and its relationship with environmental management and sustainability in the future.

This study also provided a new understanding of how big data analytics capabilities can improve the relationship between green relational capital and green supply chain performance. Big data analytics capabilities help companies respond effectively in real-time data processing [181]. Integrating these capabilities to increase cooperation with suppliers and customers could, furthermore, improve green supply chain performance. However, some results of the study were inconsistent with the previous literature. Specifically, the results revealed a lack of statistical significance for the interaction of big data analytics capabilities, green structural capital and green human capital on green supply chain performance.

6.2. Managerial Implications

The study highlighted various implications for administrators and supply chain managers in the manufacturing sector in Jordan. The study results confirmed that all components of green intellectual capital had a positive impact on the green supply chain performance. Therefore, managers should invest more in developing the skills and experience of their employees to improve their green capital, thereby enhancing the improvement of the level of sustainability in the supply chain. Managers in the Jordanian manufacturing sector should also invest in green technology and develop environmentally friendly databases. Moreover, managers should pay more attention to organizational procedures and policies that encourage the protection of the environment. This can be done by setting regulations and rules that encourage workers to think creatively regarding the environment and document these innovations in various storage systems. The study's results confirmed that green relational capital is more strongly linked to the green supply chain performance than other components. Therefore, managers should build green relational capital with key suppliers and consistently share information to ensure the implementation of environmental initiatives and programs. Furthermore, managers should provide adequate training for employees to increase their environmental awareness and also build mutual trust among employees to improve green internal integration in the green supply chain. Managers can additionally benefit from holding formal and informal meetings to increase the participation of environmental objectives with employees and even with suppliers, thus increasing environmental awareness and enhancing the green supply chain performance. The study suggests increasing managers' focus in supply chain management in the Jordanian manufacturing sector on increasing cooperation with customers by involving customers in setting the firm's environmental goals and allowing them to put their suggestions and ideas into action within the green supply chain.

The study's results revealed that big data analytics capabilities are positively related to green supply chain performance and that these capabilities moderate the positive relationship between green relational capital and green supply chain performance. Managers in this sector should enhance the technological and organizational capabilities that contribute to adopting big data analytics by investing in infrastructure and metadata and training employees in the latest technologies. In addition, managers can further benefit from big data analytics capabilities by using more than one method of data collection, such as both quantitative and qualitative data, and using social media to collect data and provide a database dedicated to this process. The study recommends managers in human resources departments in the manufacturing sector in Jordan develop incentive systems dedicated to big data initiatives to motivate employees to exploit big data technologies to create added value for the green supply chain. The study additionally recommends that managers use artificial intelligence techniques and social media to create accurate predictive models regarding customer preferences. These practices enhance the creation of added value and thus allow for high performance in the green supply chain.

6.3. Limitations and Future Research

Although this study had noteworthy results, it is subject to many limitations, which must be taken into consideration when generalizing the results of the study. First, the study data were collected through cross-sectional data, but it would be useful to understand the relationship among the study's constructs by using longitudinal data or panel data. Second, this study was conducted in the context of the manufacturing sector in Jordan, so it would be useful to conduct studies in different contexts, countries, and cultures to enable scholars and management practitioners to better understand the relationships between the components of green intellectual capital and green supply chain performance. Third, the quantitative data collected through the questionnaire were relied on to test the hypotheses and objectives of the study, but qualitative methods such as interviews were ignored when conducting the study. Thus, it would be interesting to conduct future studies based on a qualitative approach. Finally, the study suggests conducting future studies that focus on mediating constructs such as green innovation or green human resource management practices and examining more causal relationships of these constructs.

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