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Review

Review of Green Supply-Chain Management Diffusion in the Context of Energy Transformation

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Abstract: Against the background of continuously rising energy carbon emissions, accelerated energy transformation in developed countries, and increased international attention to energy security, there is still a large amount of energy consumption in the manufacturing industry. Promoting the diffusion of green supply-chain management is becoming a powerful tool to support energy transformation and energy conservation and emission reduction in the manufacturing industry. Based on this, we first conducted a scientific metrological analysis of 4960 articles in relevant fields in the Web of Science database, presenting the research status of green supply-chain management diffusion in the context of energy transformation. Second, we identified factors that affect the implementation of green supply-chain management, and analyzed the diffusion path of green supply-chain management among enterprises. Finally, based on the energy situation, enterprise operation, and implementation of environmental protection laws and regulations in Shaanxi Province, China, we determined the current situation, obstacles, and development direction of green supply-chain management diffusion of enterprises in the context of energy transformation. The research found that: at this stage, there are still some deficiencies in the research on the mechanism of green supply-chain management in the internal communication of enterprises; in the future, the diffusion of green supply-chain management can be further developed around social performance and energy transformation technology; and we can help energy transformation by strengthening policy guidance and assisting enterprise reform.

Keywords: energy transformation; green; supply-chain management; management diffusion; sustainable development

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1. Introduction

With the development of world industrialization, environmental issues have become one of the key issues in global business activities. More and more enterprises incorporate the reduction of environmental damage caused by production and operation activities into their strategic plans. Reducing carbon dioxide emissions per unit energy consumption and energy consumption per unit GDP (improving energy efficiency and adjusting energy structure) is an important part of improving environmental conditions [1]. Energy transformation not only refers to the reconstruction of energy system from power production to use, but also includes the transformation of economic and social systems caused by the digitalization and intelligentization of new energy management, transportation and use scenarios. It is the sum of transformation and upgrading to higher forms of the supply system in three aspects of energy supply, operation and consumption, driven by advanced information, communication, control, energy storage and other technologies [2]. Among them, the combination of supply-chain management (SCM) and energy management to promote the adjustment of the energy structure can improve the compatibility between manufacturing and the environment and help enterprises meet business needs more socially. This is the necessity of green supply-chain management [3]. In recent years, some scholars have conducted some reviews on the research in the field of global supply-chain management under the background of energy transformation, mainly including three

aspects. The first aspect is the scientific metrological analysis and empirical research review of the global supply chain. The second aspect is a systematic literature review of GSCM research in various industries and proposed future research topics. The third aspect is to compare the research hotspots and frontiers of GSC at home and abroad [4–8].

However, there has been little review of the diffusion mechanism of GSC in the context of energy conversion. Especially in the context of the European energy crisis caused by the interruption of the supply chain at this stage, the prices of bulk commodities in Europe continue to rise; the prices of residential hydropower and natural gas have risen significantly; and the energy problem has begun to affect people's livelihoods. Relevant research involves green consumption, green procurement, green manufacturing, and reverse logistics, etc. The management structure is complex, and coordination is difficult [9]. Therefore, in the study of GSC energy conversion, it is more necessary to look at all the factors from a holistic and comprehensive perspective, and conduct a comprehensive analysis of previous studies, so as to point out the direction for the future GSCM diffusion path.

Therefore, based on 4960 documents in the Web of Science (WoS) database, this study conducted a relevant analysis on the GSCM diffusion mechanism under the background of energy conversion. The second chapter combs the relevant research according to the time, journal type, etc. The third chapter reviews the origin and development of GSCM diffusion under the background of energy conversion. The fourth and fifth chapters focus on the driving and hindering factors of diffusion and the diffusion path. The sixth chapter takes Shaanxi Province of China as an example to analyze the current situation of GSCM diffusion under the background of energy conversion. Chapter 7 points out the direction of GSCM diffusion in the context of future research and energy conversion based on the summary of diffusion driving and hindering factors, diffusion paths and the current situation. Under the complex international division of labor, this research is committed to adding a certain theoretical basis and practical guidance for the spread of GSCM diffusion in the energy-transformation process. Research in this direction can help environmental protection, energy conservation and other factors integrate into the entire supply chain; not only can it play a significant role in solving enterprise energy problems, but it can also help alleviate the global energy crisis and improve the environmental situation.

2. Analysis on the Research Status of Green Supply-Chain Management Diffusion

In this study, the WoS database was used as the search pool to retrieve relevant documents with the themes of "Green supply chain management" and "Supply chain management diffusion". Through standardized retrieval and screening, the qualified bibliometric database was extracted, and 4960 documents were retrieved. It was found that the relevant research on the management diffusion of GSC mainly focuses on the influence of management decision-making mechanisms, driving factors, interference factors, policies and regulations from micro and macro perspectives.

2.1. Distribution of Literature Quantity over Time

According to the annual statistical analysis of the sample literature, the trend in the past ten years is shown in Figure 1. The first document on green supply-chain management in the sample was published in 1985. The number of documents published has generally been on the rise. The research on GSCM has increased significantly, and it should continue to develop rapidly after 2021.

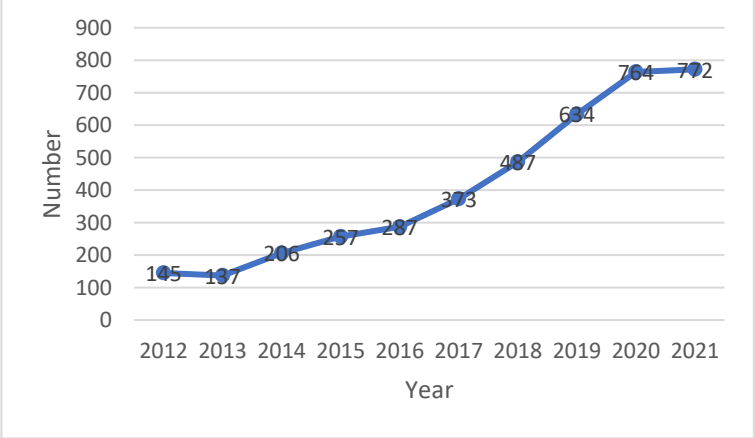

Figure 1. Distribution of literature quantity over time.

2.2. Distribution of Literature Research Fields

Figure 2 lists the top ten published fields in the field of GSCM, namely Business Economics (3619), Environmental Sciences Ecology (3437), Engineering (3384), Computer Science (1826), Science Technology Other Topics (1596), Mathematics (1555), Energy Fuels (1216), Operations Research Management Science (821), Geography (723), and Social Issues (585).

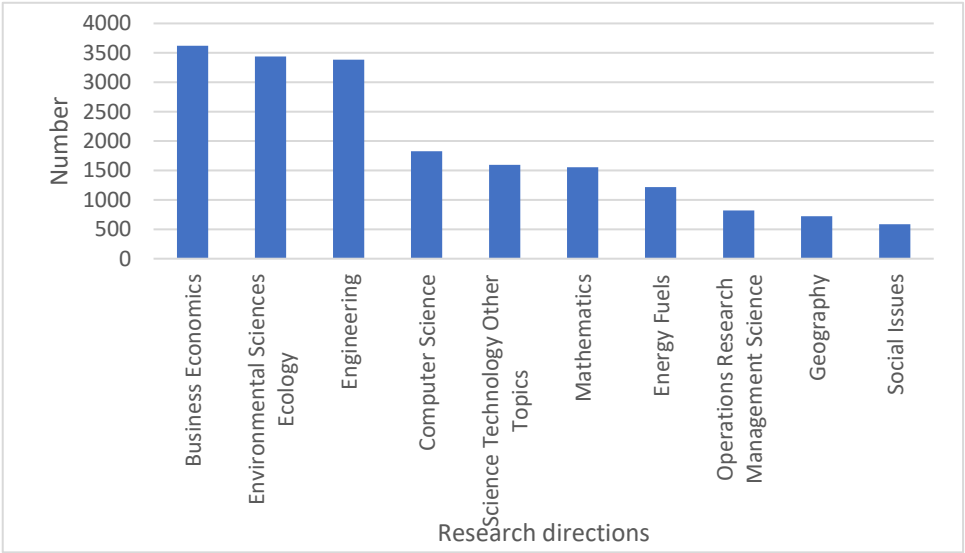

Figure 2. Distribution of literature research fields.

2.3. Source Distribution of Literature and Periodicals

Through an analysis of journal literature sources, it was concluded that the top ten journals that have published articles on GSCM are, respectively, *Journal of Cleaner Production* (755), *Sustainability* (461), *International Journal of Production Economics* (221), *International Journal of Production Research* (141), *Business Strategy and the Environment* (137), *Computers & Industrial Engineering* (112), *Resources Conservation and Recycling* (103), *Environmental Science and Pollution Research International* (97), *Environmental Science and Pollution Research* (95), and *Supply Chain Management: An International Journal* (77), as shown in Figure 3.

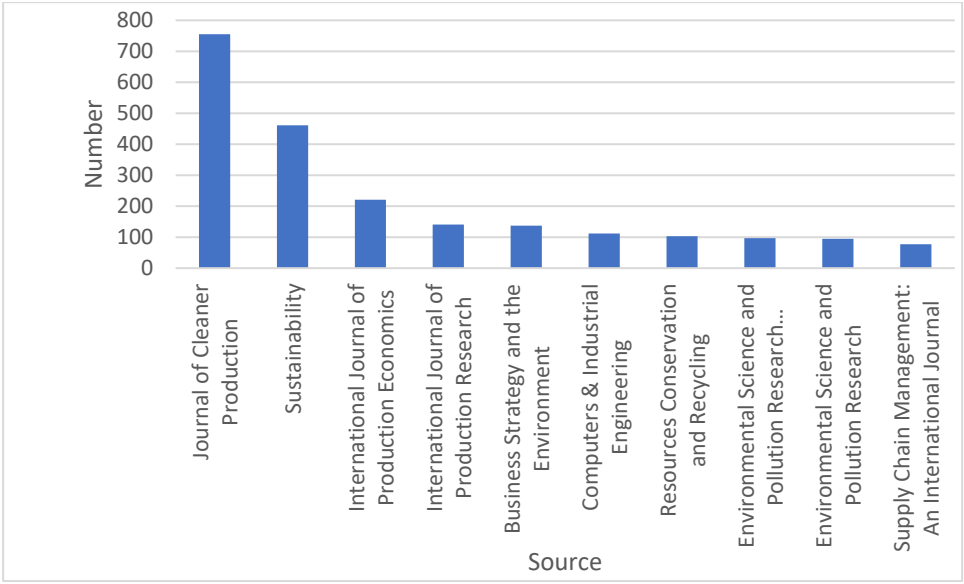

Figure 3. Source distribution of literature and periodicals.

The relevant research on GSCM can be roughly divided into four stages. The first stage is the exploration stage. The relevant research mainly focuses on the exploration of the connotation of GSCM and the definition of relevant theories, including research on the relationship between GSCM and energy transformation [10,11]. The second stage is the research stage of practical methods. The relevant research mainly focuses on the methods of improving GSCM, that is, how GSCM promotes energy transformation and upgrading [12,13]. The third stage is the effect evaluation stage. The relevant research mainly focuses on the evaluation of the GSCM framework to determine the effect of GSCM on energy transformation [14,15]. The fourth stage mainly focuses on integrating new technologies such as GSCM and big data blockchain, improving the technical level of energy transformation, and breaking through the theoretical and practical bottlenecks at this stage [16,17].

3. Method Introduction and Development of Diffusion Sources of Green Supply-Chain Management

3.1. Method Introduction

In this study, CiteSpace software was mainly used for quantitative analysis to objectively, scientifically and visually reveal the quantitative relationship among literature, sources and fields. In this paper, GSCM diffusion in the context of energy conversion is comprehensively analyzed. Diffusion path and driving factors are indispensable components. Therefore, in this study, the diffusion path, driving factors and barriers are used as keywords, and the literature with high citation rates and more representative views were selected for comprehensive analysis to sort out the current research situation. It should be pointed out that in Chapter 6, because the empirical analysis method is used to reveal the current situation of GSCM diffusion in the context of energy conversion, the entropy weight method, which is widely used in empirical research, was used to calculate the index attribute value.

3.2. Development of Diffusion Sources of Green Supply-Chain Management

Energy has always been the focus of the world. In previous studies, related studies on energy transformation mainly include research on the technology upgrading of energy transformation and research on the path of energy transformation. Among them, technological progress can improve energy utilization efficiency and eliminate technical barriers [18], while research on the path of energy transformation focuses on improving energy effi-

ciency, unconventional oil and gas exploitation, and the rise of renewable energy [19,20]. Governments have also taken extensive measures to regulate the behavior of enterprises for the purpose of energy transformation. These measures impose many constraints on enterprises with large energy consumption (especially the manufacturing industry), and affect the survival and development of enterprises. It has become a very effective response to maintain enterprise profits under many constraints, reform the existing production and operation processes, and improve the sustainable development capacity of the supply chain. This makes the global supply-chain management under the background of energy transformation more and more concerning, and more and more relevant for research.

At this stage, the widely accepted definition of GSCM is "Green supply chain is a modern management mode that comprehensively considers environmental impact and resource efficiency in the whole supply chain. It is based on green manufacturing theory and supply chain management technology, involving suppliers, manufacturers, sellers and users. Its purpose is to minimize the environmental impact (negative effect) and maximize resource efficiency of products in the whole process from material acquisition, processing, packaging, warehousing, transportation, use to scrap disposal" [21].

Since the 21st century, under a series of policies and environmental protection standards, a large number of enterprises have adopted GSCM to reduce energy consumption and enterprise costs. Since 2005, General Motors and the World Environment Center have launched a green supply-chain project in China; Ford and General Motors require their suppliers to pass the ISO14000 system certification [22]; IBM encourages its suppliers to establish effective environmental management systems. This kind of active green supply-chain management behavior not only effectively standardized the green production and operation behavior of enterprises themselves, but also played a normative and exemplary role in green production and operation behavior of upstream and downstream enterprises in their SC.

GSCM diffusion is a new supply chain development model. It refers to the process of spreading GSCM in enterprises or organizations in a certain industry or region under the influence of internal and external factors over time, and finally reaching a balance. We can analyze the diffusion of GSCM from both macro and micro perspectives. From a macro perspective, the diffusion of GSCM is the change of enterprises implementing GSCM in an industry or region. From a micro perspective, the diffusion of GSCM is a decision made by a specific enterprise to decide whether to implement GSCM and to what extent [23].

Research on diffusion behavior of GSCM should mainly include the following aspects [24]: diffusion object, which refers to the enterprises or organizations that accept diffusion in the process of GSCM (Due to the limitation of resource capacity and other factors, they have not taken or only taken part of GSCM behavior); diffusion subject refers to enterprises that have adopted GSCM practices; time and space span, the diffusion behavior of GSCM needs to spread in time and space; influencing factors include internal influencing factors and external influencing factors (The internal influencing factors mainly refer to the situation of the enterprise itself, while the external influencing factors mainly refer to the situation of policies, consumers, other enterprises, etc.); diffusion channel, the communication ways of GSCM between different enterprises, and between enterprises and the environment.

The decision-making process of enterprises on GSCM is mainly divided into four parts [25]: identification of cost, which mainly refers to the identification of the economic cost required by each link and activity of enterprises to implement GSCM and the impact on the environment; determine opportunities, judge the supply-chain links and actions with the greatest economic cost and environmental impact according to the costs determined in the previous step, determine whether GSCM should be adopted, and negotiate with upstream and downstream enterprises to jointly judge the direction of future actions; calculate the income, the cost of purchasing equipment, personnel training, operation management, etc., and the economic and environmental benefits obtained after adopting the GSCM model; decision making, implementation and monitoring based on the above

three steps, determine the GSCM behavior suitable for the enterprise, and continuously monitor and improve through cost-benefit analysis in the implementation process.

4. Influential Factors of Green Supply-Chain Management Diffusion

Through a comprehensive analysis of the literature in the literature library, it was found that research on the diffusion mechanism of GSCM at this stage mainly focuses on four aspects: internal drivers, internal obstacles, external drivers and external obstacles. Figure 4 shown factors affecting the diffusion of green supply-chain management.

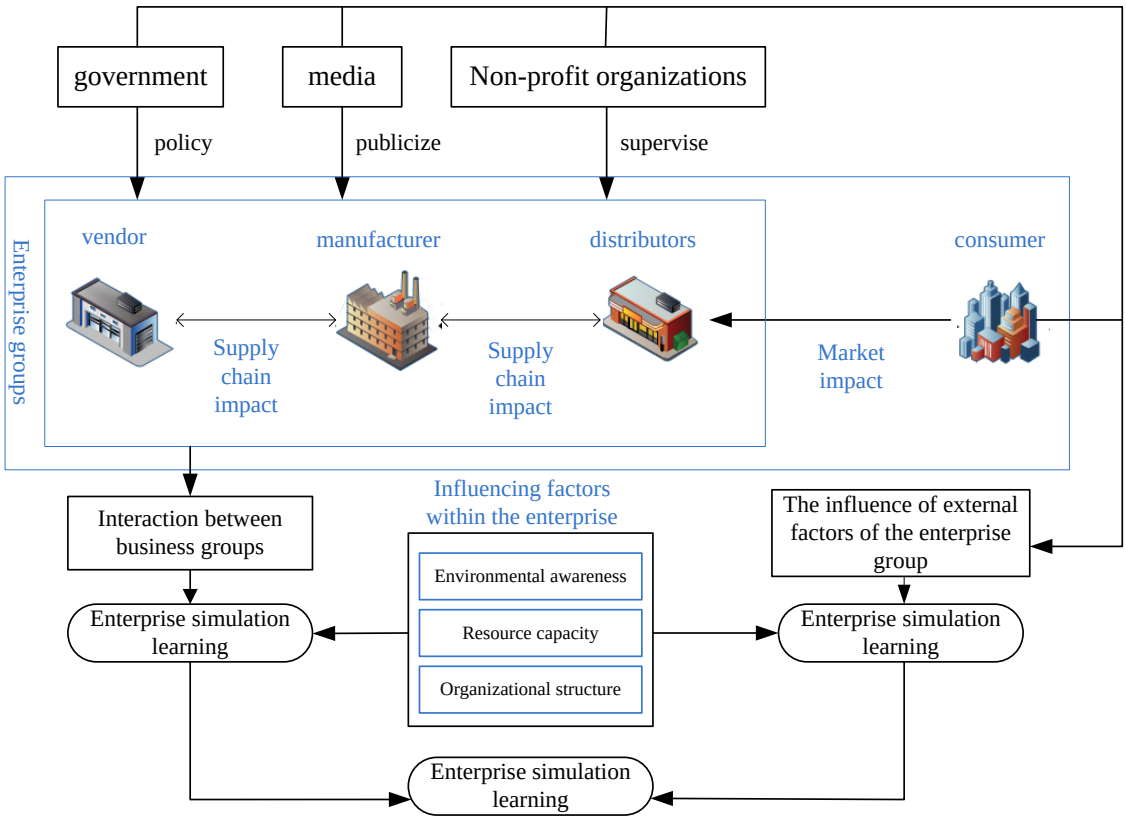

Figure 4. Factors affecting the diffusion of green supply-chain management.

4.1. Internal Drivers

Research on the internal driving factors of enterprises' acceptance of GSCM diffusion mainly focuses on three aspects: the organizational structure of enterprises; the resources of enterprises; and the economic benefits brought by the implementation of GSCM.

The personality and values of enterprise founders will affect the behavior of the entire enterprise [26]. Specifically, if enterprise founders are more inclined to assume more social responsibility and pay more attention to environmental protection, enterprises are more inclined to implement more GSCM behaviors [27]. In addition, if environmental performance is related to operational performance and employee performance, employees will be more willing to participate in the improvement of enterprise environmental performance [28]. The resources owned by enterprises and the supervision ability of enterprises play a vital role in the decision-making of GSCM. Enterprises with more resources, whether human resources or financial resources, can better bear the cost investment brought by the implementation of GSCM [29]. The positive performance of implementing GSCM to enterprises includes economic performance, environmental performance and operational performance. The main purpose for enterprises to implement GSCM is to save on costs of enterprises. On the one hand, the application of GSCM can save losses caused by a

government's punishment of enterprises' environmental pollution behavior; on the other hand, it can reduce the waste caused by industrial investment [30,31].

4.2. Internal Obstacles

The relevant research on the obstacles that enterprises face when conducting GSCM can also be summarized in three aspects: the cost and benefit changes brought about by adopting GSCM; the limitations of enterprises' own resources and management capabilities; and the lack of enterprise awareness.

In general, the initial stage of GSCM requires a lot of switching costs, and in the process of operation, there are often additional expenditures [32]. Obviously, the problem of economic benefits cannot be ignored by any enterprise, so the high switching cost hinders some enterprises from carrying out GSCM [33]. Limited resources, lack of adaptability of enterprise strategy to internal environment innovation and other factors are also important reasons that hinder enterprises from implementing GSCM [34]. The lack of enterprise awareness ability is mainly reflected in the lack of awareness of social responsibility of enterprise leaders, low attention to environmental protection, and the lack of green technology development, corresponding human resources and other capabilities of enterprises [35].

4.3. External Drivers

Relevant research on the external factors that affect the diffusion of GSCM can also be roughly divided into three parts: the impact of policies and regulations; other enterprise behaviors in the supply chain; and other factors such as consumers and media.

Policies and regulations around the world are gradually shifting from "end of pipe governance" to "full life-cycle control". The pressure of regulations is often the most important factor that causes enterprises to implement GSCM. Enterprises will meet the requirements of government environmental regulations through environmental innovation [36,37]. The behavior of other enterprises in the supply chain includes not only upstream and downstream enterprises, but also their competitors [38,39]. The GSCM behavior of cooperative enterprises tends to spread from larger enterprises to smaller enterprises. Because consumers will consider the green attribute of enterprises when purchasing, it will have a certain impact on enterprises' adoption of GSCM. Some non-governmental organizations often promote enterprises' GSCM by influencing public awareness [40].

4.4. External Obstacles

Similarly, policies and regulations that are unfavorable to GSCM will also inhibit the implementation of GSCM by enterprises [41]. Incomplete environmental protection laws and regulations, lax implementation, imperfect market supervision, and less punishment for enterprises' environmental pollution behavior will inhibit the GSCM behavior of enterprises [42].

If other enterprises and their competitors in the supply chain do not implement GSCM and do not require the upstream and downstream enterprises in the supply chain to protect the environment, other enterprises in the supply chain also lack the motivation to implement GSCM [43,44]. From the perspective of consumers and other social organizations, if consumers are indifferent to the environmental protection behavior of enterprises and GSCM ideas are not popularized, enterprises will also lack the motivation to implement GSCM behavior [45].

In order to display the research related to classification and to summarize it more intuitively and clearly, it is shown in Table 1.

Table 1. Relevant research on driving and hindering factors for enterprises to implement green supply-chain management.

Field	Factor	Related Literature
Internal drivers	Organization structure	Subhani et al. [26]; Long et al. [27]
	Resource capacity	Abbas et al. [28]; Khatib et al. [29]
	Positive performance	Dhanavanth et al. [30]; Lee et al. [31]
Internal obstacles	Economic loss	Zhang et al. [32]; Choi et al. [33]
	Lack of resource capacity	Tasmia et al. [34]
	Lack of consciousness	Dube et al. [35]
External drivers	Policies and regulations	Fang et al. [36]; Meng et al. [37]
	Other enterprises in the supply chain	Guo et al. [38]; Jiang et al. [39]
	Consumers and other social organizations	Ji et al. [40]
External obstacles	Policies and regulations	Srivastava et al. [41]; Vinay et al. [42]
	Other enterprises in the supply chain	Peng et al. [43]; Boruchowitch et al. [44]
	Consumers and other social organizations	Heydari et al. [45]

5. Diffusion Path of Green Supply-Chain Management

Through the analysis of the relevant research on the diffusion path of GSCM, we found that the diffusion of GSCM among enterprises mainly spreads in the supply chain, including not only the mutual communication of enterprises in the supply chain, but also the mutual communication of enterprises with competitive relationships in the SC.

5.1. Spread by Downstream Customers of the Supply Chain

The demand for green product manufacturing of subordinate enterprises in the supply chain is often transmitted to upstream suppliers, because upstream suppliers need to manufacture products according to the demand of downstream enterprises [46]. It should be noted that these customer needs may affect the behavior of enterprises in the SC for a long time, thus urging them to complete the GSCM practice. That is to say, when there are more advanced enterprises implementing GSCM in the downstream of the supply chain, the upstream enterprises of the supply chain are often not limited to the products supplied to the downstream customers, but gradually extend to the whole process of enterprise management. In addition, some more advanced enterprises often require not only their suppliers to provide green products, but also an overall level of green management. This is because these enterprises realize that the green management practices of a single enterprise cannot achieve its overall environmental objectives [47]. Downstream enterprises in the SC will demand green manufacturing and green management from upstream enterprises, which is often because of the demands of the end consumers.

5.2. Spread by Upstream Suppliers of the Supply Chain

There are few articles focusing on the spread of GSCM by upstream suppliers of the supply chain, but it is undeniable that the spread of GSCM by upstream suppliers cannot be ignored. The suppliers will provide some valuable suggestions when implementing the green management project, and the active participation of suppliers will greatly improve the efficiency of the whole GSC construction.

5.3. Spread among Peer Competitors

The implementation of GSCM can help enterprises gain competitive advantage in fierce market competition. In other words, by implementing GSCM, enterprises can gain a better image, so that consumers are more willing to buy their products. Therefore, enterprises that implement GSCM can obtain greater market share and higher economic benefits. Driven by interests, competitive enterprises in the same market will also join in the practice of GSCM, and GSCM can spread among peer competitive enterprises.

In order to display the research related to classification and summarize it more intuitively and clearly, it is shown in Table 2.

Table 2. Green supply-chain diffusion path.

Diffusion Path	Author	Primary Coverage
Downstream customers of the supply chain	Hamlfield et al. [48]	American furniture manufacturers require their suppliers to improve their green management
	Lamming et al. [49]	British automobile manufacturers require their suppliers to improve green management
	Lippman [50]	General enterprises put forward green management requirements for their suppliers
Upstream suppliers of the supply chain	Carter et al. [51]	The supplier will provide some valuable suggestions when implementing the green management project
	Vachon et al. [52]	Supplier cooperation can help enterprises find the most effective practical path of green supply-chain management
Competitive enterprises in the same industry	Henriques et al. [53]	Competitive enterprises may affect the formulation of industry standards and regulations
	Zhu et al. [54]	Enterprises' green behaviors are affected by their competitors

It was found that at this stage, research on the diffusion path of GSCM is mainly concentrated among enterprises, focusing on the influence of one or some factors on enterprise GSCM, but ignoring the influence of the correlation between the internal influencing factors of enterprises, and lacking research on the propagation mechanism of GSCM in enterprises [55]. On the other hand, research on the communication of GSCM among enterprise groups also pays little attention to the construction of diffusion models. The research focuses on the identification and qualitative role of influencing factors, and less on quantitative methods.

6. Current Situation of Green Supply-Chain Management Diffusion

Shaanxi Province is an important region with great development vitality, innovation ability and radiation-driving role in western China; its green sustainable development ability directly affects the overall sustainable development level of western China. Shaanxi enterprises are in the primary stage of implementing GSCM and are facing more serious environmental problems. Therefore, this study selected the Shaanxi Province of China as the research object to explore the implementation status of GSCM diffusion and to analyze the future research direction.

6.1. Index System Construction

Based on the research framework of GSCM diffusion and the dynamic model for enterprises to implement GSCM [56–58], combined with the current situation of Shaanxi Province and expert opinions, this study analyzed the current situation of GSCM diffusion in Shaanxi Province from two perspectives (internal influencing factors of enterprises, external influencing factors of enterprise groups), six aspects, and 27 indicators (where "+" represents driving factors and "-" represents hindering factors), as shown in Table 3. The purpose was to find the deficiencies in Shaanxi Province and provide a basis for the conclusion.

Table 3. Assessment indicators for the development status of green supply chain of Shaanxi enterprises.

Target Layer	Criterion Layer	Indicator Layer	Tendentiousness
Research on the diffusion of enterprise green supply-chain management in shaanxi province	Internal influencing factors of the enterprise		
	Enterprise technology R&D and resource capacity	Number of various technical contracts	+
		Turnover of various technical contracts (CNY 100 million)	+
		R&D internal expenditure (CNY 10 thousand)	+
		Number of new product development projects of industrial enterprises above designated size	+
		New product development expenditure (CNY 10 thousand)	+
		Sales revenue of new products (CNY 10 thousand)	+
		Number of R&D personnel in industrial enterprises above designated size	+
		Number of R&D personnel	+
		Number of enterprise units	+
		Total assets (100 million)	+
		Total profit (100 million)	+
	Industrial comprehensive energy consumption and pollutant emission	Production of general industrial solid waste (10 thousand tons)	-
		Total industrial wastewater discharge (10 thousand tons)	-
		Total industrial waste gas emission (100 million m^3)	-
		Industrial power consumption (100 million kwh)	-
	Assessment of industrial ecological protection	Reduction rate of energy consumption per unit GDP (%)	+
		Comprehensive utilization of general industrial solid waste (10 thousand tons)	+
		Number of wastewater treatment facilities	+
		Number of waste gas treatment facilities	+
	External influencing factors of enterprise group		
	Traffic infrastructure	Length of highway line (km)	+
		Length of railway line (km)	+
		Freight volume (10 thousand tons)	+
		Turnover (million ton kilometers)	+
	Policy	Policy	
		Shaanxi green manufacturing list	
	Consumer preference for green products	Consumers' awareness of environmental protection	
		Consumer emission reduction behavior	

The data of Shaanxi Province in the past five years obtained from "the Statistical Yearbook of Shaanxi Province" and "the Statistical Yearbook of China" are as shown in Table 4:

Table 4. 2016–2020 Shaanxi green supply-chain management diffusion data.

Indicator Layer	2016	2017	2018	2019	2020
Internal influencing factors of the enterprise					
Number of various technical contracts	21,033	31,355	37,952	53,004	49,928
Turnover of various technical contracts (CNY 100 million)	802.74	921.55	1125.28	1467.83	1533.68
R&D internal expenditure (CNY 10 thousand)	419.56	460.94	532.41	584.58	632.33
Number of new product development projects of industrial enterprises above designated size	4506	5093	6103	7595	9810

Table 4. *Cont.*

Indicator Layer	2016	2017	2018	2019	2020
New product development expenditure (CNY 10 thousand)	189.82	204.25	235.06	265.45	306.32
Sales revenue of new products (CNY 10 thousand)	123.65	1714.89	2033.36	2566.04	2494.19
Number of R&D personnel in industrial enterprises above designated size	70,832	70,156	56,926	63,105	/
Number of R&D personnel	27,881	29,023	24,359	27,053	/
Number of enterprise units	5799	6208	6426	6974	7145
Total assets (100 million)	28,939.56	30,642.94	32,432.48	35,958.91	36,879.34
Total profit (100 million)	1550.02	2238.04	2436.27	2306.17	1978.88
Production of general industrial solid waste (10 thousand tons)	8647.85	10,080.7	11,146.49	11,788.27	12,430.05
Total industrial wastewater discharge (10 thousand tons)	28,416.76	30,875.52	21,722.42	23,901.4	26,080.38
Total industrial waste gas emission (100 million m^3)	16,288.44	19,455.77	18,386.05	20,704.95	23,023.85
Industrial power consumption (100 million kwh)	906.57	1027.02	1128.91	1258.81	1323.34
Reduction rate of energy consumption per unit GDP (%)	3.83	4.19	4.89	1.39	1.89
Comprehensive utilization of general industrial solid waste (10 thousand tons)	6639.24	3424.57	3393.77	4222.44	6443.38
Number of wastewater treatment facilities	1765	1750	1758	/	1996
Number of waste gas treatment facilities	4627	6677	7742	/	6535
External influencing factors of enterprise group					
Length of highway line (km)	172,471	174,395	177,128	180,070	180,660
Length of railway line (km)	7807	8655	8714	10911	11,339
Freight volume (10 thousand tons)	149,049	163,086	173,253	154,758	165,268
Turnover (million ton kilometers)	344,591	376,163	402,599	348,345	369,845
Policy	/	/	/	/	/
Shaanxi green manufacturing list	/	/	/	/	/
Consumers' awareness of environmental protection	/	/	/	/	/
Consumer emission reduction behavior	/	/	/	/	/

6.2. Data Processing Method

In this study, the entropy weight method was selected for objective weighting of the indicator system, which is more objective and accurate than other subjective weighting methods such as AHP, thus ensuring scientificity of the research model and standardization of the research process.

Due to differences in the effects of various evaluation indicators on the current situation of GSCM in Shaanxi Province, and the different magnitudes of each indicator, this study introduced a range standardization method to process the data. Through the establishment of the evaluation model, the evaluation indicators of the evaluation object were obtained.

The standard value calculation formulas of positive and negative indicators are:

positive indicators, $R_{ij} = \frac{x_{ij} - \min x_i}{\max x_i - \min x_i}$ and

negative indicators, $R_{ij} = \frac{\max x_i - x_{ij}}{\max x_i - \min x_i} = 1 - \frac{x_{ij} - \min x_i}{\max x_i - \min x_i}$, where

x_{ij} is the original value of the index in row i and column j (the original value of the evaluation index in item i of the research object j); R_{ij} represents the normalized standard value; and $\max x_i$ and $\min x_i$ are the maximum and minimum values of indicators in row i, that is, the maximum and minimum values of indicators.

After the standardization of the positive and negative indicators, the entropy weight method was used to calculate the indicator weight in order to make the calculation of each evaluation indicator weight more accurate and objective, based on the standardized data. After determining the weight of each evaluation index, we calculated the comprehensive score of Shaanxi's 2016–2020 green supply-chain management diffusion level, and obtain the comprehensive development score E. The calculation formula is as follows:

$$E = \sum_{i=1}^{m} W_i \times S_{ij},$$

where W_i is the index weight of each index layer; S_{ij} is the score of each ecological and urbanization-coordinated development index.

6.3. Calculation Results and Analysis

The current scores of Shaanxi green supply-chain diffusion from 2016 to 2020 were 0.2061, 0.2033, 0.2096, 0.1901, 0.1908, respectively. It can be seen that the management diffusion of Shaanxi GSC is still in the initial stage, and changed little with the year. Considering the differences of specific single indicators and the impact of unquantifiable policies, consumers' environmental awareness and other behaviors, it can be assessed that the management diffusion of Shaanxi's green supply chain has the following characteristics at this stage.

Enterprise energy consumption is still rising. The data show that the emission of industrial wastes is still on the rise. Although the energy consumption per unit GDP and enterprise innovation are developing well, the momentum is weak, which is not enough to offset the rising consumption demand of industrial energy, so that the diffusion status has not been significantly improved.

Industry restrictions lead to problems in the energy structure of enterprises and lack of reform-driving force. Most enterprises in Shaanxi Province belong to high-pollution industries such as machinery manufacturing, textiles and non-ferrous metals. These are mainly traditional industrial production methods, with high energy consumption and pollution emissions, lack of technological innovation, and lack of subjective initiative to implement GSCM. In addition, carrying out the reform of GSCM requires a lot of money, manpower and material resources. Affected by the epidemic, the social economy is inactivated, and overall corporate profits have declined, which cannot guarantee the funds needed for implementing GSCM.

Policies and regulations have weak restrictions on energy consumption. At present, most of the policies and regulations on environmental protection and emission reduction aim to achieve carbon emission reduction in the whole society. The measures and systems are broad and lack specific measurement standards, which is not conducive to the implementation of enterprises in management practice. Most only emphasize emissions reduction at the end of the SC, and cannot promote the green transformation of the SC from the root level. In addition, the policies and regulations emphasize the punishment mechanism, focusing on the punishment of enterprises that fail to meet the basic environmental requirements. Ignoring the fact that the fines paid by enterprises in violation of the law are often lower than the cost required to comply with the law and lacking incentive mechanisms for enterprises to actively practice GSCM.

There is a lack of model leading enterprises, and the strong green product preference information of consumers has not been effectively transmitted. At present, the number of enterprises implementing GSCM in Shaanxi Province is small, and the radiation effect on upstream and downstream enterprises of the SC is poor. Consumers generally have the concept of green and low-carbon and are willing to consume green. However, due

to the high price of green products, many limitations of products, imperfect supporting facilities, difficulties in sustainable use of products and other factors, the sales of some green products are not good, which makes enterprises not be aware of the strong green preference of consumers, and lack the motivation for reform.

7. Conclusions

Although the current research has carried out some beneficial explorations on various factors affecting the diffusion of GSCM and their roles in the context of energy transformation, which provides good reference for subsequent scholars, there are the following limitations.

In terms of energy transformation: first, there is little research on energy transformation technology in the supply chain and it is worth studying what technical measures can be taken to reduce energy consumption in the whole chain from product design to raw material procurement, production, transportation, warehousing, recycling and remanufacturing; second, under the condition that there are a large number of energy restriction policies, how to make the policies play a better role is another issue worthy of in-depth discussion; third, there is a lack of relevant research on the role of GSC in promoting enterprise-energy transformation. (Green supply chain plays an important role in promoting enterprise energy conservation and consumption reduction, optimizing energy consumption structure and other aspects. There is a lack of summary and development path analysis of relevant roles.); fourth, there is a lack of relevant analysis on the challenges of green supply chain in energy transformation.

In terms of diffusion theory: first, there is a lack of research on the correlation between the internal influencing factors of GSCM enterprises; second, scholars in relevant fields focus on the impact of the relationship factors between enterprise groups on the implementation of GSCM, therefore, making it is necessary to identify the complex relationships within enterprises and analyze the diffusion mechanism of the implementation of GSCM; third, there is a lack of research on the implementation of GSCM diffusion models among enterprise groups. (Scholars in related fields mainly use qualitative description or statistical analysis methods to study the impact of external factors of enterprises to identify and analyze the impact factors and their qualitative roles.); fourth, the quantitative research on the influence of external factors of enterprises on the diffusion of GSCM within enterprises and among enterprise groups is also relatively small.

Based on the overall understanding of the current research situation of GSCM, the future research direction of GSCM is prospected, mainly including the following aspects:

(1) Focus on the technical level of green supply-chain energy transformation. Use blockchain, Internet of Things and other new technologies to realize and improve product traceability, carbon footprint tracking, green product recycling and other GSCM diffusion methods. Focus on the role of green supply chain in promoting enterprise energy transformation and the challenges in the process of energy transformation. In terms of policy guidance, enterprise reform, etc., according to the bottleneck faced by the GSCM diffusion at this stage, countermeasures should be studied.

(2) Focus on the benefits of energy transformation of enterprise GSCM. Explore the benefits that enterprises will gain from implementing GSCM. Not only should the economic benefits be considered, but also the social benefits should be included in the scope of research. At the same time, research in various fields outside the manufacturing industry should be further carried out. Government, non-governmental organizations and consumer groups play an important role in the management and diffusion of the green supply chain, and such groups are very concerned about social benefits. Enterprises should ensure the comprehensive improvement of economic, social and environmental benefits. Therefore, social benefits such as employee satisfaction and welfare level can be included in the research scope of GSCM diffusion, thus promoting the supply chain energy transformation.

(3) We can carry out research on the diffusion mechanism of GSCM. Identify the key factors affecting supply-chain management, analyze the extent to which these factors affect

the nodes and structure of the supply chain, and study the diffusion mechanism of GSCM; build the framework of the GSCM diffusion system, and deeply analyze the influence of various factors on the diffusion of GSCM among enterprises; build a diffusion model of GSCM, and deeply reveal the influence of internal and external factors of the government on the diffusion of GSCM among enterprise groups.

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References

1. Kostka, G.; Goron, C. From Targets to Inspections: The Issue of Fairness in China' s Environmental Policy Implementation. *Environ. Polit.* **2021**, *30*, 513–537. [CrossRef]
2. Jorgebson, D.W.; Wilcoxen, P.J. Environmental regulation and US economic growth. *Rand J. Econ.* **1990**, *21*, 314–340. [CrossRef]
3. Hell, J. Environmental supply chain dynamics. *J. Clean. Prod.* **2000**, *8*, 455–471. [CrossRef]
4. Bhatia, M.; Gangwani, K.K. Green supply chain management: Scientometrie review and analysis of empirical research. *J. Clean. Prod.* **2021**, *284*, 124722. [CrossRef]
5. Zhang, D.; Rong, Z.; Ji, Q. Green innovation and firm performance: Evidence from listed companies in China. *Resour. Conserv. Recy.* **2019**, *144*, 48–55. [CrossRef]
6. Badi, S.; Murtagh, N. Green supply chain management in construction: A systematic literature review and future research agenda. *J. Clean. Prod.* **2019**, *223*, 312–322. [CrossRef]
7. Zhou, X.; Li, T. A bibliometric analysis of comparative research on the evolution of international and Chinese green supply chain research hotspots and frontiers. *Environ. Sci. Pollut. Res.* **2021**, *28*, 302–6323. [CrossRef]
8. Asha, L.N.; Dey, A.; Yodo, N.; Aragon, G. Optimization Approaches for Multiple Conflicting Objectives in Sustainable Green Supply Chain Management. *Sustainability* **2022**, *14*, 12790. [CrossRef]
9. Tseng, M.L.; Islam, M.S.; Karia, N.; Fauzi, F.A.; Afrin, S. A literature review on green supply chain management: Trends and future challenges. *Resour. Conserv. Recy.* **2019**, *141*, 145–162. [CrossRef]
10. William, E.; Kilbourne, S.C.; Beckmann, E.T. The role of the dominant social paradigm in environmental attitudes: A multinational examination. *J. Bus. Res.* **2002**, *55*, 193–204.
11. Maianan, I.; Mcalister, D.T. Socially responsible organizational buying: How can stakeholders dictate purchasing policie. *J. Micromarket.* **2003**, *23*, 78–89. [CrossRef]
12. Zhu, Q.; Sarkis, J.; Lai, K.H. Examining the effects of green supply chain management practices and their mediations on performance improvements. *Int. J. Prod. Res.* **2012**, *50*, 1377–1394. [CrossRef]
13. Jabbour CJ, C.; Da Silva, E.M.; Paiva, E.L.; Santos, F.C. Environmental management in Brazil: Is it a completely competitive priority? *J. Clean. Prod.* **2012**, *21*, 11–22. [CrossRef]
14. Gandhi, S.; Mangla, S.K.; Kumar, P.; Kumar, D. A combined approach using AHP and DEMATEL for evaluating success factors in implementation of green supply chain management in Indian manufacturing industries. *Int. J. Logist.-Res. App.* **2016**, *19*, 537–561. [CrossRef]
15. Shi, P.; Yan, B.; Shi, S.; Ke, C. A decision support system to select suppliers for a sustainable supply chain based on a systematic DEA approach. *Inform. Technol. Manag.* **2015**, *16*, 39–49. [CrossRef]
16. Mubarik, M.; Rasi, R.Z.R.M.; Mubarak, M.F.; Ashraf, R. Impact of blockchain technology on green supply chain practices: Evidence from emerging economy. *Manag. Environ. Qual. Int. J.* **2021**, *32*, 1023–1039. [CrossRef]
17. Bag, S.; Viktorovich, D.A.; Sahu, A.K.; Sahu, A.K. Barriers to adoption of blockchain technology in green supply chain management. *J. Glob. Oper. Strateg. Sourc.* **2021**, *14*, 104–133. [CrossRef]
18. Yah, N.F.; Oumer, A.N.; Idris, M.S. Small scale hydro-power as a source of renewable energy in Malaysia: A review. *Renew. Sust. Energ. Rev.* **2017**, *72*, 228–239. [CrossRef]
19. Lopes, H.S.; Remoaldo, P.C.; Ribeiro, V.; Martín-Vide, J. Pathways for adapting tourism to climate change in an urban destination—Evidences based on thermal conditions for the Porto Metropolitan Area (Portugal). *J. Environ. Man.* **2022**, *315*, 115161. [CrossRef]
20. Gernaat, D.E.; de Boer, H.S.; Daioglou, V.; Yalew, S.G.; Müller, C.; van Vuuren, D.P. Climate change impacts on renewable energy supply. *Nat. Clim. Chang.* **2021**, *11*, 119–125. [CrossRef]
21. Webb, L. Green purchasing: Forging a new link in the supply chain. *Resourse* **1994**, *6*, 14–18.
22. Jiang, R.H.J.; Bansal, P. Seeing the need for ISO 14001. *J. Manag. Stud.* **2003**, *40*, 1047–1067. [CrossRef]

23. Walker, H.; Di, S.L.; McBain, D. Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *J. Purch. Supply. Manag.* **2008**, *1*, 69–85. [CrossRef]
24. Hazen, B.; Cegielski, C.; Hanna, J.B. Diffusion of green supply chain management Examining perceived quality of green reverse logistics. *Int. J. Logist. Manag.* **2011**, *22*, 373–389. [CrossRef]
25. Peattie, K.; Ringler, A. Management and the environment in the UK and Germany; a comparison. *Eur. Manag. J.* **1994**, *12*, 216–225. [CrossRef]
26. Subhani, M.I.; Hasan, S.A.; Osman, M. Impact of Organization Culture on Promoting Green Supply Chain. *Am. J. Sci. Res.* **2012**, *82*, 108–112.
27. Long, Q.; Tao, X.; Chen, Y.; Chen, Y.; Xu, L.; Zhang, S.; Zhang, J. Exploring combined effects of dominance structure, green sensitivity, and green preference on manufacturing closed-loop supply chains. *Int. J. Prod. Econ.* **2022**, *251*, 108537. [CrossRef]
28. Abbas, J.S. Impact of knowledge management practices on green innovation and corporate sustainable development: A structural analysis. *J. Clean. Prod.* **2019**, *229*, 611–620. [CrossRef]
29. Al-Khatib, A. Big data analytics capabilities and green supply chain performance: Investigating the moderated mediation model for green innovation and technological intensity. *Bus. Process Manag. J.* **2022**, *28*, 1446–1471. [CrossRef]
30. Dhanavanth, R.M.; Ziaul, H.M.; Hans-Joachim, S.; Sebastian, K. A review of green supply chain management: From bibliometric analysis to a conceptual framework and future research directions. *Resour. Conserv. Recy.* **2018**, *139*, 150–162.
31. Pik-Yin, L.; Voon-Hsien, T.; Garry, W.; Ooi, K. A gateway to realising sustainability performance via green supply chain management practices: A PLS-ANN approach. *Expert. Syst. Appl.* **2018**, *107*, 1–14.
32. Zhang, B.; Jun, B.I.; Liu, B. Drivers and barriers to engage enterprises in environmental management initiatives in Suzhou Industrial Park. *Front. Environ. Sci. Eng.* **2009**, *3*, 11. [CrossRef]
33. Choi, T.; Luo, S. Data quality challenges for sustainable fashion supply chain operations in emerging markets: Roles of blockchain, government sponsors and environment taxes. *Transp. Res. Part E Logist. Transp. Rev.* **2019**, *131*, 139–152. [CrossRef]
34. Tumpa, T.J.; Ali, S.M.; Rahman, M.H.; Paul, S.K.; Chowdhury, P.; Khan, S.A.R. Barriers to green supply chain management: An emerging economy context. *J. Clean. Prod.* **2019**, *236*, 117617. [CrossRef]
35. Anil, S.; Dube, R.R. Analysis of green supply chain barriers using integrated ISM-fuzzy MICMAC approach. *Benchmarking* **2016**, *23*, 1558–1578.
36. Fang, Z.; Kong, X.; Sensoy, A.; Cui, X.; Cheng, F. Government's awareness of Environmental protection and corporate green innovation: A natural experiment from the new environmental protection law in China. *Econ. Anal. Policy* **2021**, *70*, 294–312. [CrossRef]
37. Qing, M.; Li, M.; Liu, W.; Li, Z.; Zhang, J. Pricing policies of dual-channel green supply chain: Considering government subsidies and consumers' dual preferences. *Sustain. Prod. Consump.* **2021**, *26*, 1021–1030.
38. Guo, S.; Choi, T.M.; Shen, B. Green product development under competition: A study of the fashion apparel industry. *Eur. J. Oper. Res.* **2020**, *280*, 523–538. [CrossRef]
39. Jiang, P.; Yi-Chung, Y.; Ghi-Feng, T.; Shu, J. Green supplier selection for sustainable development of the automotive industry using grey decision-making. *Sustain. Dev.* **2018**, *26*, 890–903. [CrossRef]
40. Ji, J.; Zhi, Z.; Yang, L. Carbon emission reduction decisions in the retail-/dual-channel supply chain with consumers' preference. *J. Clean. Prod.* **2017**, *141*, 852–867. [CrossRef]
41. Srivastava, S.K. Green supply-chain management: A state-of-the-art literature review. *Int. J. Manag. Rev.* **2007**, *9*, 53–80. [CrossRef]
42. Vinay, S.; Yadav, A.R.; Singh, R.D. Blockchain technology adoption barriers in the Indian agricultural supply chain: An integrated approach. *Resour. Conserv. Recy.* **2020**, *161*, 104877.
43. Peng, Y.; Wang, W.; Li, S.; Veglianti, E. Competition and cooperation in the dual-channel green supply chain with customer satisfaction. *Econ. Anal. Policy* **2022**, *76*, 95–113. [CrossRef]
44. Boruchowitch, F.F.; Morgane, M.C. Who in the firm can create sustainable value and for whom? A single case-study on sustainable procurement and supply chain stakeholders. *J. Clean. Prod.* **2022**, *363*, 132619. [CrossRef]
45. Heydari, J.; Govindan, K.; Basiri, Z. Balancing price and green quality in presence of consumer environmental awareness: A green supply chain coordination approach. *Int. J. Prod. Res.* **2021**, *59*, 1957–1975. [CrossRef]
46. Noci, G.; Vergandi, R. Managing 'green' product innovation in small firms. *R&D Manag.* **1999**, *1*, 3–15.
47. Lee, S.Y. Drivers for the participation of small and medium-sized suppliers in green supply chain initiatives. *Supply Chain. Manag.* **2008**, *13*, 185–198. [CrossRef]
48. Handfield, R.B.; Walton, S.V.; Seegers, L.K.; Melnyk, S.A. Green value chain practices in the furniture industry. *J. Oper. Manag.* **1997**, *4*, 293–315. [CrossRef]
49. Lamming, R.; Hampson, J. The environment as a supply chain management issue. *Brit. J. Manag.* **1996**, *7*, S45–S62. [CrossRef]
50. Lippman, S. Supply chain environmental management. *Environ. Qual. Manag.* **2001**, *11*, 11. [CrossRef]
51. Carter, C.R.; Dresner, M. Purchasing's role in environmental management: Cross-functional development of grounded theory. *Supply Chain. Manag.* **2001**, *3*, 12–26. [CrossRef]
52. Vachon, S.; Klassen, R.D. Extending green practices across the supply chain—The impact of upstream and downstream integration. *Int. J. Oper. Prod. Man.* **2006**, *26*, 795–821. [CrossRef]
53. Henriques, I.; Sadorsky, P. The relationship between environmental commitment and managerial perceptions of stakeholder importance. *Acad. Manag. J.* **1999**, *42*, 87–99. [CrossRef]

54. Zhu, Q.H.; Sarkis, J.; Lai, K.H. Green supply chain management innovation diffusion and its relationship to organizational improvement: An ecological modernization perspective. *J. Eng. Technol. Manag.* **2012**, *29*, 168–185. [CrossRef]
55. Peng, Z.; Shuaizhi, G.; Yue, L.; Ge, Z. Energy transition management towards a low-carbon world. *Front. Eng.* **2022**, *9*, 499–503.
56. Lockley, A.; Hippel, T.V. The carbon dioxide removal potential of Liquid Air Energy Storage: A high-level technical and economic appraisal. *Front. Eng. Manag.* **2021**, *8*, 9. [CrossRef]
57. Tang, M.; Walsh, G.; Lerner, D.; Fitza, M.A.; Li, Q. Green innovation, managerial concern and firm performance: An empirical study. *Bus. Strategy. Environ.* **2018**, *27*, 39–51. [CrossRef]
58. Seman, N.A.A.; Govindan, K.; Mardani, A.; Zakuan, N.; Saman, M.Z.M.; Hooker, R.E.; Ozkul, S. The me diating effect of green innovation on the relationship between green supply chain management and environmental performance. *J. Clean. Prod.* **2019**, *229*, 115–127. [CrossRef]