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Driving mechanism of green supply chain integration on green innovation under environmental uncertainty: Mediating role of knowledge sharing

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Abstract: Traditional approaches to promoting green innovation (GI) have problems such as isolated local innovation, lack of collaboration and systematization, and excessive focus on short-term benefits. This paper proposes using the mediating role of knowledge sharing (KS) to influence green supply chain integration (GSCI) with environmental uncertainty (EU) factors, thereby promoting the realization of GI. Through this integration, the problems of isolated innovation and short-term benefit orientation in traditional methods are solved, and GI's collaborative and systematic development is promoted. Firstly, a questionnaire on the effect of GSCI is designed, and then descriptive statistical analysis is used to understand the basic situation of GSCI and related control variables. Multiple linear regression is used to test whether GSCI can affect GI, and mediation effect analysis is then used to test whether KS can play a mediating role. Finally, interaction regression analysis is used to explore whether the EU can moderate the impact of GSCI on GI. In the experimental analysis, whether GSCI can affect GI is tested. The p-values of the six dimensions in GSCI show significance, indicating that GSCI directly impacts GI. When testing whether there are mediation and moderation effects, Paths 1-3 are all significant, and the confidence interval is [-0.424, -0.07], which does not include 0. KS has a partial mediation effect between GSCI and GI. The p-value of GSCI*EU is 0.004, which is less than 0.05 and is significant, indicating that the EU plays a moderating role between GSCI and GI.
Keywords: *Driving mechanism, Environmental uncertainty, Green innovation, Green supply chain integration, Knowledge sharing.*

1. Introduction

In an increasingly complex and uncertain global economy, companies face challenges from policies, technologies, markets, etc. Green supply chain integration (GSCI) and green innovation (GI) have become key strategies to cope with these challenges. Especially in the context of the high environmental uncertainty (EU), effectively integrating GSCI and promoting sustainable development goals through GI have become important topics of concern in academic and practical fields. EU factors, including policy changes, market demand fluctuations, unstable environmental regulations, and the speed of technological innovation, have increased the risks faced by companies. To meet these challenges, companies need to increase their efforts in green technology innovation and implement green practices in all links of the supply chain to ensure competitiveness in an uncertain environment. The core of GSCI lies in cross-company and cross-departmental collaboration, optimizing the environmental benefits of the overall supply chain through improving green technology, recycling resources, reducing pollution, etc. With the increasingly stringent global environmental protection policies and the increasing demand for green products from consumers, GSCI has become the key for companies to gain market competitive advantages. By strengthening cooperation among all parties in the supply chain, companies can enhance their GI capabilities and promote upstream and downstream partners to jointly develop green technologies and promote the sustainable development of the supply chain. However, the EU has also increased the complexity of the GI process. GI involves not only product and technology innovation but

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also innovations in management models, market strategies, and resource utilization. When facing changes in the external environment, companies face more challenges, such as high risk in green technology research and development, difficulty in predicting demand for green products, and frequent changes in policies and regulations. These uncertainties may have a negative impact on the company's GI process, so companies need to have the ability to respond flexibly to the EU. In this context, knowledge sharing (KS) plays an important role as a mediating mechanism between GSCI and GI. KS is not limited to technical exchanges but also involves information sharing on market trends, policy changes, consumer demand, supply chain management, etc. By sharing key green technologies, experiences, and information with partners, companies can reduce uncertainty in the innovation process and better respond to challenges brought by the external environment. For example, suppliers and manufacturers can share technologies for new environmentally friendly materials; retailers and manufacturers can communicate about consumers' environmental preferences; governments and companies can predict new environmental policies through information sharing. The flow of this information helps companies seize GI opportunities more quickly, accelerate innovation decisions, and improve the market adaptability of green products.

As a key mediating mechanism, KS promotes the cross-organizational flow of implicit environmental knowledge and green technology, which not only alleviates the information asymmetry problem caused by external environmental fluctuations but also drives incremental and breakthrough GI through knowledge reorganization and collaborative learning. This driving mechanism presents dynamic evolution characteristics. When the EU is high, close supply chain integration accelerates the transfer of environmental protection technology through structured KS channels (such as joint research and development platforms and green databases). Informal knowledge exchange (such as interaction between technicians and sharing of environmental protection experience) in moderate uncertainty situations is more effective in stimulating innovation inspiration. The application of digital technology has significantly enhanced the depth and breadth of KS, enabling supply chain members to capture changes in environmental regulations and market demand fluctuations in real time and thereby adjust the direction of innovation. It is worth noting that the effect of this mechanism is subject to the boundary constraints of the degree of trust between organizations and the ability to absorb knowledge. Only when supply chain node companies have sufficient environmental knowledge decoding capabilities and establish trust relationships based on environmental commitments can the mediation effect of KS be fully released. Ultimately, a virtuous cycle of "integration-sharing-innovation" is formed, achieving a dual improvement in environmental performance and economic performance.

The innovations of this paper are as follows: First, through regression analysis, whether the six dimensions of GSCI can affect GI is tested, which preliminarily confirms the direct relationship between GSCI and GI. Then, how GSCI affects GI is further explored, and whether KS plays a mediating role is tested. The mediation effect analysis helps to reveal the mechanism between GSCI and GI, that is, the path by which GSCI affects GI through KS. Next, an interaction regression analysis is applied to explore how the EU moderates the impact of GSCI on GI, that is, to understand whether the EU can change the intensity of the impact of GSCI on GI.

2. Theoretical Framework and Hypotheses

GI refers to promoting environmental protection and sustainable development through innovation in technology, management, business models, etc. Takalo and Tooranloo [1] comprehensively reviewed the systematic literature on GI. Xiang, et al. [2] empirically analyzed the role of the government in the GI financing activities of listed companies based on a Poisson regression model of panel data. Khanra, et al. [3] contributed to existing research by providing authoritative articles on GI as a solid resource and proposing an agenda for future research. Soewarno, et al. [4] studied the role of GI strategy in promoting the development of environmental protection technology. Luo, et al. [5] analyzed the direct impact, mediating role, and regional spillover effects of the digital economy on GI. Yin and Yu [6] used a method combining hierarchical regression and fuzzy set qualitative comparative analysis to explore

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the implementation path of company digital GI practices and how green knowledge generation supported by digital technology can improve innovation outcomes. Quan, et al. [7] studied how the CEO's (Chief Executive Officer) overseas experience affects the GI of companies. Song, et al. [8] studied effective ways to achieve sustainable development of GI. Yu, et al. [9] explored how green finance policies can help companies solve GI financing problems. Li, et al. [10] analyzed the effect of digital finance on GI. Sun, et al. [11] studied the impact of GI and institutional quality on energy efficiency. Yuan and Cao [12] explored the driving effect of company social responsibility and green dynamic capabilities on GI. Singh, et al. [13] studied the interaction between green human resource management and green transformational leadership, GI, and environmental performance. Irfan, et al. [14] empirically analyzed the impact mechanism of inclusive green finance on GI and the effect of policy intervention through the difference-in-differences model, mediation effect model, and panel vector autoregression model. Seman, et al. [15] explored the relationship between green supply chain management and GI practices. Tu and Wu [16] revealed the mediating role of organizational learning in GI promoting company competitive advantage. Liu, et al. [17] studied the impact of company characteristics, environmental actions, and industry characteristics on GI. Peng, et al. [18] constructed a framework of environmental regulation, GI intention, and GI behavior. They explored the mediation effect of green technology innovation intention. Based on the technology-organization-environment framework, Zhang, et al. [19] examined the degree of company preparedness for GI from three aspects: technology preparation, organizational preparation, and environmental preparation. El-Kassar and Singh [20] measured the impact of GI implementation and its drivers on a company's performance and competitive advantage.

KS is the behavior of active communication, integration, and application of various knowledge resources between different subjects. Ahmed, et al. [21] reviewed the current research status on the application of social media in KS. Safdar, et al. [22] reviewed and confirmed that there is a positive correlation between the variable self-efficacy and KS. Azeem, et al. [23] concluded that organizational culture is indispensable to the success of business operations, and KS and organizational innovation are key drivers for gaining competitive advantage. The research by Swanson, et al. [24] showed that KS and employee job performance can directly affect employee loyalty. Ganguly, et al. [25] studied the role of implicit KS in promoting organizational innovation capabilities. Wang and Hu [26] found that KS plays a mediating role between collaborative innovation and innovation performance. Le and Lei [27] evaluated the mediating role of KS and the impact of organizational support on innovation capability. Nauman, et al. [28] compared and tested the pros and cons of two mediating mechanisms, collaborative culture, and KS, on the impact of servant leadership on team performance. Mohamed, et al. [29] proposed a new KS-based nature-inspired algorithm to solve optimization problems in continuous space. The research by Singh, et al. [30] showed that the knowledge values and KS practices of managers in companies affect open innovation. Open innovation, as a driving force for the performance of small and medium-sized enterprises, in turn, affects organizational performance. Kucharska and Erickson [31] studied the relationship between KS and job satisfaction. Purwanto, et al. [32] studied the relationship between transformational leadership, management innovation, KS, and market performance. Kremer, et al. [33] believed that KS is a prerequisite for innovation and a key factor in helping employees become innovation leaders. Shujahat, et al. [34] explored the key mediating role of knowledge worker productivity between knowledge generation, KS, and knowledge application and innovation. Ansari and Khan [35] found that online social media as a collaborative learning tool significantly impact the interaction between students and teachers and online KS behavior.

As shown in Figure 1, This study constructs a theoretical framework for the impact mechanism of GSCI on GI based on resource-based theory, organizational environment theory and resource coordination capability theory. Resource-based theory explains how GSCI forms competitive advantages by integrating green resources, and proposes hypotheses H1-H6: The six dimensions of GSCI have a significant positive impact on GI. Resource coordination capability theory explains the mediating role of KS (H7), emphasizing the realization of innovation transformation through resource reset, reorganization and reconstruction. Organizational environment theory further reveals the moderating effect of EU (H8), indicating that the impact of resource coordination capability on innovation performance will be enhanced in a dynamic environment. This theoretical framework organically combines the static resource view, dynamic capability perspective and environmental contingency factors, and systematically explains the internal mechanism of GSCI affecting GI.

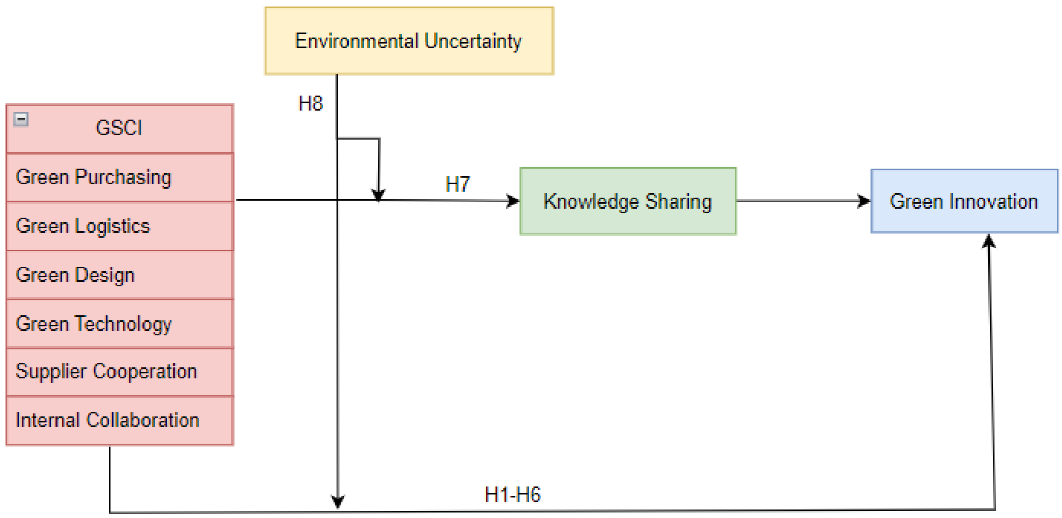

Figure 1.
Core concept diagram.

3. Methods

3.1. Questionnaire Design and Process

The data source of this paper is collected through questionnaires. The design framework of the questionnaire is based on resource-based theory, Resource orchestration capabilities, and organizational environment theory. The questionnaire is mainly used to evaluate the effect of GSCI, and it includes four modules, such as GSCI, GI, KS, and EU. GSCI includes six dimensions, namely green procurement, green logistics, green design, green technology, supplier cooperation, and internal collaboration. Through questions in these six dimensions, the questionnaire comprehensively assesses the degree of GSCI while gaining in-depth insights into the role of GSCI in promoting GI, as well as its relationship with KS and EU. Each dimension in the questionnaire contains relevant questions, and respondents rate it based on five options (1-5 points). These questions are designed to explore how GSCI affects the GI outcomes of companies and to analyze the mediating role of factors such as KS and EU in GSCI.

This study uses a questionnaire survey method, focusing on high resource consumption and high environmental impact industries in China's manufacturing industry (such as electronics, automobiles, chemicals, etc.), to investigate the green supply chain management and green innovation practices of enterprises. Table 1 shows the measurement scales of the four core variables in the study.

Table 1.
Original scales of the four variables.

Variables	Definition	Example variables
Green supply chain integration (independent variable)	Assume that factors directly affect the results	(Green procurement): selection of environmentally friendly suppliers, material recyclability requirements, supplier environmental performance evaluation, environmental weight in procurement decisions (Green logistics): use of low-carbon transportation tools, green packaging materials, logistics energy consumption optimization, reverse logistics management (Green design): application of ecological design principles, product life cycle analysis, disassembly design, frequency of green design training (Green technology): investment in clean production technology, real-time monitoring of production energy consumption, advanced waste treatment technology, depth of external technical cooperation (Supplier cooperation): joint environmental training, green innovation project collaboration, environmental data sharing mechanism, long-term green supplier incentives (Internal collaboration): frequency of cross-departmental green meetings, weight of employee environmental performance assessment, green innovation resource investment, intensity of senior executive environmental goal review
Green innovation (dependent variable)	Quantitative results used to assess the impact of independent variables	Number of low-carbon products, process energy efficiency improvement, green patents, industry recognition
Knowledge sharing (mediating variable)	Explain the intermediate mechanisms by which independent variables affect dependent variables	Technical seminars, policy information sharing, tacit knowledge transfer, knowledge management system
Environmental uncertainty (moderating variable)	Variables that moderate the relationship between the independent and dependent variables	Policy fluctuations, market demand fluctuations, technology iteration speed, international policy impact, etc.

In Figure 2, the specific process of this paper includes several key steps to ensure that the research process is clear, structured, and orderly. First, through the collection and preprocessing of questionnaire data, reliable basic data is provided for subsequent analysis. During the data collection stage, it is crucial to ensure the representativeness of the sample and the integrity of the data. Then, descriptive statistical analysis is performed on the collected data to understand the basic distribution characteristics and main trends of the data, such as the score distribution of each dimension, the basic situation of the respondents, etc. This can help provide an intuitive understanding and reference for subsequent in-depth analysis. This phase allows researchers to ensure data quality and identify any potential anomalies or biases. This analysis process not only helps researchers clearly break down the entire data analysis process but also avoids confusion and bias in the analysis, ensuring that the research process proceeds in an orderly manner. Through the precise design and implementation of each step, the research can be gradually advanced and ultimately draw systematic and reliable conclusions, thereby improving the credibility and validity of the research.

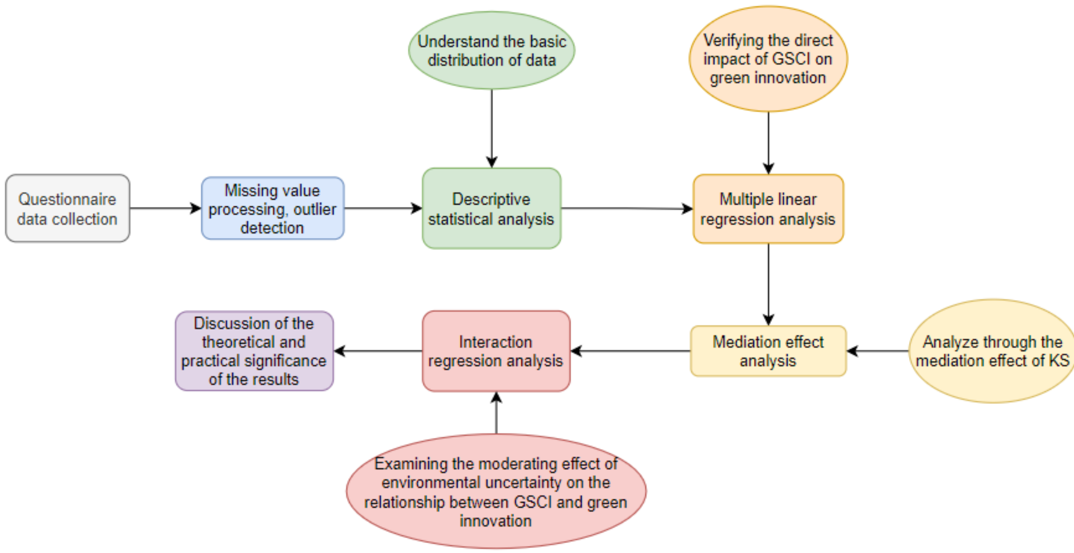

Figure 2.
Process framework of this paper.

3.2. Descriptive Statistic Methods

A total of 468 questionnaires are distributed, 424 of which are collected, including 31 invalid questionnaires. There are a total of 393 valid questionnaires, accounting for 92.7%. The questionnaire data is imported into Spsspro, making sure that the score of each questionnaire question is entered as a separate variable. The answer to each question (1-5 points) needs to be entered as a variable in Spsspro. For example, the four questions in the green procurement dimension are combined into a green procurement variable, and the average score of the four variables is used as the value of the variable. For each variable, Spsspro can automatically calculate descriptive statistical indicators, such as mean, standard deviation, minimum, maximum, skewness, and kurtosis. The formula for the mean is:

$$Mean(\mu) = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (1)$$

The formula for the standard deviation is:

$$\text{Standard Deviation(s)} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu)^2} \qquad (2)$$

The definition of skewness is:

$$Skewness = \frac{N}{(N-1)(N-2)}\sum_{i=1}^{N}\left(\frac{x_i - \mu}{s}\right)^3 \qquad (3)$$

The definition of kurtosis is:

$$Kurtosis = \frac{N(N+1)}{(N-1)(N-2)(N-3)}\sum_{i=1}^{N}\left(\frac{x_i - \mu}{s}\right)^4 - \frac{3(N-1)^2}{(N-2)(N-3)} \qquad (4)$$

3.3. Multiple Linear Regression

Multiple linear regression is adopted to test whether GSCI can affect GI. Using the variable scores in 3.2, where these variables correspond to the various dimensions of GSCI, the scores of each dimension are used as different indicators in GSCI. Considering multiple dimensions, the multiple linear equation is:

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$$GI = \beta_0 + \beta_1 \cdot GSCI_1 + \beta_2 \cdot GSCI_2 + ... + \beta_6 \cdot GSCI_6 + \in \quad (5)$$

Among them, β_0 is the constant term, which is the intercept. β_1 - β_6 are the regression coefficients of GSCI. $\in$ is the error term.

First, the scores of GI-related questions and the scores of each dimension in GSCI are extracted from the questionnaire, and these scores are entered into Spsspro. Multiple linear regression requires that the relationship between the dependent variable and the independent variable is linear, and there is no multicollinearity. VIF (Variance Inflation Factor) can be used to test collinearity. The formula is:

$$VIF_i = \frac{1}{1 - R_i^2} \quad (6)$$

Among them, R_i^2 is the value of R^2 in the regression equation of the *i*-th independent variable with all other independent variables.

Then, the p-value is used to test whether GSCI has a significant effect on GI. The p-value is calculated based on the t-statistic and t-distribution. The formula of the t-statistic is:

$$t = \frac{\hat{\beta}_i}{SE(\hat{\beta}_i)} \quad (7)$$

Among them, $\hat{\beta}_i$ represents the estimated value of the regression coefficient. $SE(\hat{\beta}_i)$ represents the standard error, indicating the uncertainty of the estimated value.

The formula for the p-value is:

$$p = P(|T| \geq |t|) \quad (8)$$

Finally, the fitting effect of the model is tested by the coefficient of determination, and its formula is:

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}} \quad (9)$$

3.4. Mediation Effect Analysis

To use the mediation effect to test whether KS plays a mediating role between GSCI and GI, four paths should be established: Path 1: testing the direct impact of GSCI on GI; Path 2: testing the impact of GSCI on KS; Path 3: testing the impact of KS on GI. The scores of multiple dimensions in GSCI are integrated and averaged to facilitate the subsequent calculation process. The formula for Path 1 is:

$$GI = \beta_0 + \beta_1 \cdot GSCI + \in \quad (10)$$

The formula for Path 2 is:

$$KS = \beta_0 + \beta_2 \cdot GSCI + \in \quad (11)$$

Path 3 is defined as:

$$GI = \beta_0 + \beta_3 \cdot KS + \in \quad (12)$$

If Paths 1, 2, and 3 are all significant, whether there is a mediation effect can be tested, which is defined as:

$$\text{Indirect Effect} = \beta_2 \cdot \beta_3 \quad (13)$$

Among them, the Indirect Effect is Path 4, which is the path by which GSCI affects GI through KS.

Finally, the Bootstrap method is adopted to test the significance of the mediation effect. The Bootstrap is set to 5,000 times, and the confidence interval is 95%. Bootstrap extracts a large number of

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samples and calculates the indirect effect of each sample to obtain its distribution and confidence interval. If the confidence interval does not contain 0, the mediation effect is significant.

Figure 3 shows the process of mediation effect analysis. First, whether GSCI has a direct effect on GI is tested. If the effect is significant, whether the mediation path is significant is tested. If the path is significant, the Bootstrap method is then used to test the indirect effect. If the result is significant, it means that there is a mediation effect.

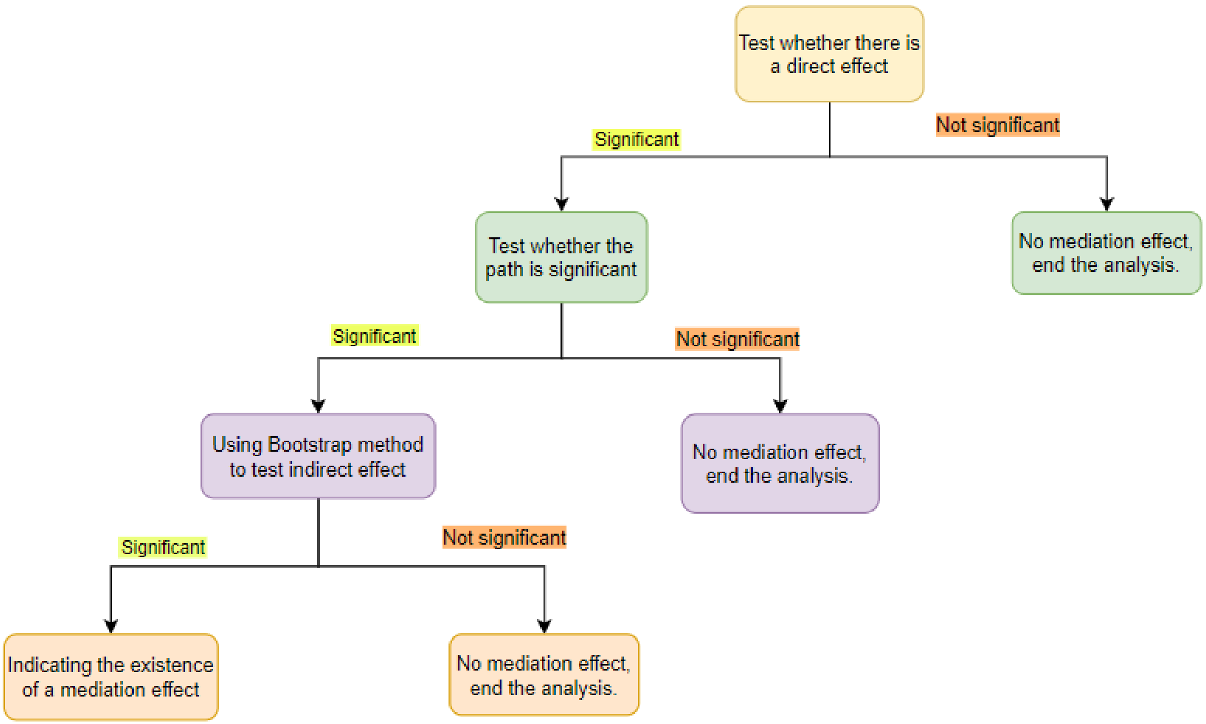

Figure 3.
Mediation effect analysis process.

3.5. Interaction Regression Analysis

Interaction regression is a method of applying interaction terms in regression analysis, which is usually used to analyze the mutual influence between independent variables. Interaction regression helps understand how one independent variable affects the dependent variable with the influence of another independent variable. An interaction term should be created to use interaction regression to test whether EU moderates the impact of GSCI on GI. The formula is:

$$\text{Interactio n Term} = GSCI \times EU \qquad (14)$$

The interaction term is obtained by multiplying GSCI and EU. In the Spsspro operation, a new variable should be created.

Then, the regression analysis is used to test whether the interaction term is significant. If it is significant, it means that the EU plays a moderating role in the relationship between GSCI and GI. The formula of the regression model is:

$$GI = \beta_0 + \beta_1 \cdot GSCI + \beta_2 \cdot EU + \beta_3 \cdot (GSCI \times EU) + \in \qquad (15)$$

Among them, β_3 is the key point. If it is significant, it means that it plays a moderating role.

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4. Experimental Analysis

4.1. Questionnaire Data

A total of 393 valid questionnaires are collected in this paper, and 10 questionnaires are randomly selected for data display in Table 2. The data obtained in Table 2 are the values after mean calculation, that is, the average value of four questions in one dimension or module.

Table 2.
Some questionnaire data.

Questionnaire Number	Green procurement	Green Logistics	Green Design	Green Technology
1	4.75	2.50	3.75	3.25
2	3.50	4.50	3.50	3.50
3	5.00	5.00	4.75	4.25
4	4.25	4.75	5.00	5.00
5	3.50	3.50	4.25	4.50
6	4.00	3.25	4.00	5.00
7	5.00	5.00	4.50	3.75
8	4.25	3.75	3.50	4.25
9	3.75	4.50	4.25	2.75
10	4.50	4.75	2.50	2.25
Supplier Cooperation	Internal Collaboration	GI	KS	EU
4.00	4.25	4.75	3.50	4.50
3.75	2.00	3.50	2.25	5.00
4.25	5.00	3.75	3.75	4.50
4.50	4.75	3.25	3.50	3.50
5.00	4.25	4.00	4.50	4.75
4.75	4.00	4.25	4.00	4.25
4.00	3.50	4.75	3.75	5.00
3.50	3.75	5.00	3.50	2.75
3.75	2.50	3.50	4.25	3.75
2.75	4.25	4.50	4.75	3.50

In Table 2, the first questionnaire scores an average of 4.75 points in green procurement, 2.50 points in green logistics, 3.75 points in green design, 3.25 points in green technology, 4.00 points in supplier cooperation, 4.25 points in internal collaboration, 4.75 points in GI, 3.50 points in KS, and 4.50 points in EU. Through this sample data display, the average score results of each dimension or module of the questionnaire can be intuitively understood.

4.2. Mean, Standard Deviation, Skewness, and Kurtosis of Questionnaire Data

This paper preprocesses the data from the 393 collected questionnaires. The 10 questionnaires selected as samples in 4.1 have a relatively small sample size, and the analysis results obtained may have large errors, so the stability and representativeness may be affected to a certain extent. Therefore, the sample needs to be expanded. After the expansion, the sample size is 100 questionnaires. The data is in an Excel table. This paper uses Spsspro to calculate and find that the average values of the six dimensions of GSCI in Figure 4, namely green procurement, green logistics, green design, green technology, supplier cooperation, and internal collaboration, are 3.868, 3.962, 4.000, 3.978, 4.050, and 3.895, respectively. The average value of GI is 4.045; the average value of KS is 3.978; the average value of EU is 3.947.

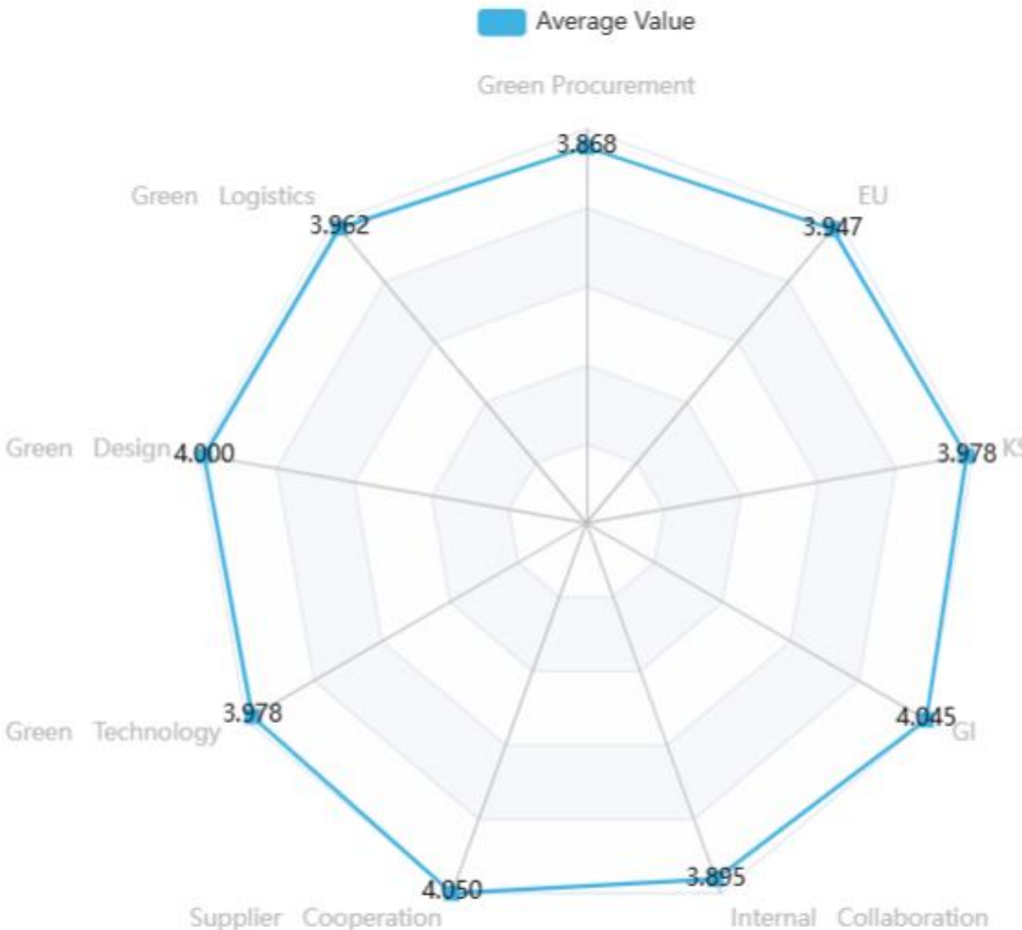

Figure 4.
Calculated average values.

Table 3 lists the standard deviation, variance, skewness, and kurtosis calculated by Spsspro.

Table 3.
Standard deviation, variance, skewness, and kurtosis indicators.

	Standard Deviation	Variance	Skewness	Kurtosis
Green Procurement	0.417	0.174	-0.025	0.274
Green Logistics	0.462	0.214	-0.024	0.176
Green Design	0.379	0.144	1.909	-0.619
Green Technology	0.404	0.163	3.223	-0.732
Supplier Cooperation	0.392	0.154	0.207	0.125
Internal Collaboration	0.444	0.197	3.202	-0.763
GI	0.373	0.139	-0.447	0.409
KS	0.371	0.138	3.753	-0.750
EU	0.388	0.151	0.369	0.243

According to Table 3, the standard deviations of the six dimensions of GSCI are 0.417, 0.462, 0.379, 0.404, 0.392, and 0.444, respectively. The kurtosis is 0.274, 0.176, -0.619, -0.732, 0.125, and -0.763, respectively. The skewness is -0.025, -0.024, 1.909, 3.223, 0.207, and 3.202, respectively. The standard deviation of GI is 0.373; the kurtosis is 0.409; the skewness is -0.447.

4.3. Testing Whether GSCI Can Affect GI

There are six dimensions in GSCI. To explore whether these six dimensions can affect GI, Spsspro software is used for calculation. Table 4 lists the linear regression analysis results.

Table 4.
Linear regression analysis results.

	B	t	p	VIF
Constant	1.281	4.285	0.000***	---
Green Procurement	0.675	11.334	0.000***	1
Green Logistics	0.404	5.714	0.000***	1
Green Design	0.434	4.868	0.000***	1
Green Technology	0.343	3.975	0.000***	1
Supplier Cooperation	0.485	5.872	0.000***	1
Internal Collaboration	0.504	7.425	0.000***	1

According to Table 4, the intercept is 1.281, and there are β_1=0.675, β_2=0.404, β_3=0.434, β_4=0.343, β_5=0.485, and β_6=0.504. The entire linear regression equation is Y=1.281+ $0.675X_1+0.404X_2+0.434X_3+0.343X_4+0.485X_5+0.504X_6$. The p-values of the six dimensions in GSCI are all 0.000*** . The VIF values are all 1, indicating no multicollinearity. At the same time, the hypothesis (H1-H6) is also verified, and the six dimensions of GSCI all have significant positive effects on GI.

4.4. Testing Whether There Are Mediation and Moderation

Before testing whether KS plays a mediating role between GSCI and GI, it is necessary to integrate and average the six dimensions in GSCI to obtain a column of GSCI variables. Based on the Spsspro software calculation, the significance of Paths 1-3 is analyzed. Tables 5, 6, and 7 list the specific situations.

Table 5.
Significance of Path 1.

	B	**t**	**p**	R^2	**Adjusted** R^2
Constant	1.572	3.129	0.003***	0.298	0.286
GSCI	0.624	4.922	0.000***		
Dependent Variable: GI					

Table 6.
Significance of Path 2.

	B	**t**	**p**	R^2	**Adjusted** R^2
Constant	1.36	2.659	0.010**	0.312	0.3
GSCI	0.656	5.08	0.000***		
Dependent Variable: KS					

Table 7.
Significance of Path 3.

	B	**t**	**p**	R^2	**Adjusted** R^2
Constant	1.68	5.187	0.000***	0.353	0.347
KS	0.593	7.315	0.000***		
Dependent Variable: GI					

According to Tables 5, 6, and 7, the equation of Path 1 is Y=1.572+0.624X; the equation of Path 2 is Y=1.36+0.656X; the equation of Path 3 is Y=1.68+0.593X. There are β_2=0.656 and β_3=0.593. All three paths are significant, so whether there is a mediation effect can be tested. According to Formula (13), the indirect effect is $\beta_2 \times \beta_3 \approx 0.389$.

After testing with the Bootstrap method, the confidence interval obtained is [-0.424, -0.07]. This confidence interval does not include 0, indicating that GSCI does affect GI, but this impact may be negative through the mediating mechanism, which suggests the existence of a partial mediation effect.The H7 hypothesis was verified, and GSCI can indirectly and positively affect GI through KS.

Whether the EU can play a moderating role between GSCI and GI is tested. There is no interaction regression analysis method in Spsspro. Therefore, it is necessary to create an interaction term, that is, GSCI*EU. Then, the linear regression analysis is used. Figure 5 presents the specific results.

In Figure 5, the p-value of the constant is 0.02; the p-value of GSCI is 0.033; the p-value of EU is 0.004; the p-value of GSCI*EU is 0.004***, all of which reject the null hypothesis and are significant. The key point is that the p-value of GSCI*EU is less than 0.05, This verifies the H8 hypothesis that EU can positively regulate the effect of GSCI on GI.

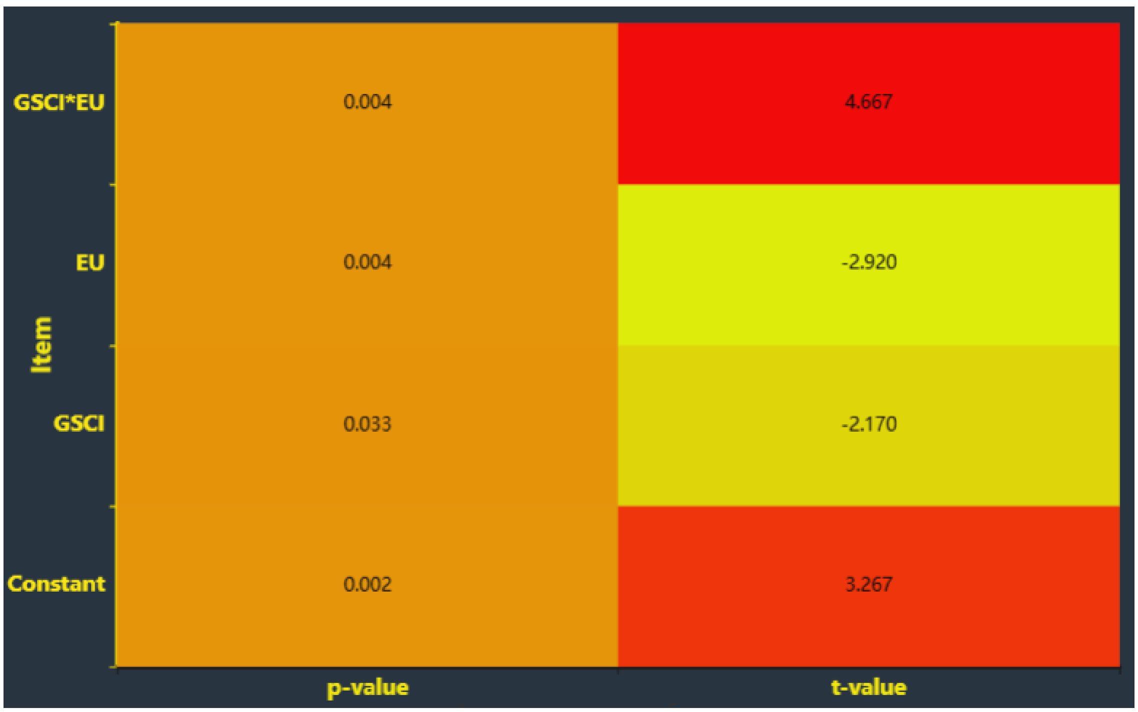

Figure 5.
Linear regression results.

5. Conclusion

In testing whether GSCI can affect GI, the p-values of the six dimensions in GSCI are all 0.000***, rejecting the null hypothesis and showing significance, which indicates that GSCI has a direct impact on GI. When testing whether there are mediation and moderation, Paths 1-3 are all significant, and the confidence interval is [-0.424, -0.07], which does not include 0, indicating that KS has a partial mediation effect between GSCI and GI. The p-value of GSCI*EU is 0.004***, which is less than 0.05 and is significant, indicating that EU plays a moderating role between GSCI and GI. The shortcoming is that the EU is a macro variable, involving uncertainties at multiple levels such as policy, technology, and market demand. Current research may capture this variable through simplified measurement methods while ignoring the impact of different types of uncertainty on GSCI and GI. In addition, in the current study, KS is proposed as a mediating variable, but the specific mechanism is not deep enough. In future research, the different dimensions of the EU should be divided more finely, such as policy uncertainty, technological uncertainty, market uncertainty, etc., and their impact on GSCI and GI should be examined separately. In future research, the multi-dimensional role of KS can also be discussed in depth, such as the type (such as technical knowledge, market knowledge, and management knowledge) and quality (such as the operability and applicability of knowledge) of KS. Moreover, the dynamic mechanism of KS can be studied, including the impact of trust, cooperative relationships, incentive mechanisms, and other factors on the effect of KS.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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