*sustainability*

MDPI

*Article*

# Social, Environmental, and Governance Factors on Supply-Chain Performance with Mediating Technology Adoption

**Weijia Li and Ziyang Liu ***

Department of Global Business, Kyonggi University, Suwon 16227, Republic of Korea; weijia1006@naver.com
* Correspondence: victor@kgu.ac.kr

**Abstract:** The COVID-19 pandemic has brought significant risks and challenges to businesses. In order to restore the supply chain, this paper incorporates social, environmental, and governance (ESG) factors into the study of corporate supply chains. The aim is to explore the factors that influence supply-chain resilience and performance from these three perspectives, with a particular focus on the role of willingness to adopt green innovation technologies. To encompass a wider audience and multiple industry sectors, this study employs a questionnaire survey method, targeting managers of Chinese companies, and utilizes analytical tools such as SPSS 26.0 and AMOS 26.0 for data analysis and validation. The research findings indicate that supply-chain collaboration, supply-chain management capabilities, supply-chain risks, and green-product innovation have a positive impact on a firm's willingness to adopt innovative technologies, subsequently leading to positive effects on supply-chain resilience and performance. By incorporating ESG factors into the scope of supply-chain research, this study expands the research domain and scope of ESG. Additionally, enhancing corporate social responsibility awareness and sustainable development consciousness holds great significance for the recovery of enterprise supply-chain development. This study also offers new insights for businesses to enhance their supply-chain management.

**Keywords:** ESG; supply-chain; green-product innovation; new technology adoption intention

check for updates

**Citation:** Li, W.; Liu, Z. Social, Environmental, and Governance Factors on Supply-Chain Performance with Mediating Technology Adoption. *Sustainability* **2023**, *15*, 10865. https://doi.org/10.3390/su151410865

Academic Editor: Giada La Scalia

Received: 31 May 2023
Accepted: 5 July 2023
Published: 11 July 2023



## 1. Introduction

In recent years, the sudden outbreak of the COVID-19 pandemic has posed significant risks and challenges to businesses worldwide. The pandemic has disrupted global supply chains, putting a strain on production lines and international logistics. Unlike everyday risks, supply-chain disruptions are difficult to predict but can potentially cause significant losses to businesses and entire supply-chain networks [1–4]. Supply-chain interruptions have become one of the critical factors affecting enterprises' sustainable development and competitiveness. Therefore, the supply-chain system needs a high degree of flexibility to cope with unforeseen events. This flexibility is called supply-chain resilience, which enables the supply-chain to maintain relative stability and reduce losses in complex and volatile environments. How to facilitate the rapid recovery of a company's supply-chain has become a focal point of scholarly attention [5–7].

Reflecting on the previous literature, scholars have made significant progress in the area of supply-chain management. However, much of the research has emphasized the risk perspective, suggesting that improving the ability to manage risks is crucial for competitive advantage. Some scholars have pointed out the correlation between supply-chain risks and system resilience [8]. Additionally, some scholars have delved into the definition of supply-chain resilience [9]. They assert that it encompasses both the capability to overcome vulnerabilities within the supply-chain and the ability to mitigate supply-chain risks [10–14]. In exploring the relationship between supply-chain risks and supply-chain resilience, Stewart et al., (1997) have put forth, through an extensive literature research, that reducing supply-chain risks can bolster supply-chain resilience [15]. However, with the deepening of industrial specialization and the diversification of customer demands, the scope and complexity of supply chains have significantly expanded compared to in the past. Some scholars argue that supply-chain resilience is a particularly intricate subject that demands a holistic perspective (Arsovski, Arsovski, Stefanović, Tadić, and Aleksić, 2017) [16]. Against this backdrop, a narrow focus on studying supply-chain risks alone is insufficient. It is necessary to expand the research by considering factors that influence the resilience and performance of corporate supply chains, specifically in the domains of environmental, social, and corporate governance (ESG) performance, as well as the Technology–Organization–Environment (TOE) theory. By building upon existing research, an exploration of these factors can provide a comprehensive understanding of supply-chain resilience.

The concept of ESG first emerged in 2006, attracting immediate attention in academia, government, and the business community (Atkins, 2020) [17]. Several scholars have validated the crucial role of ESG in supply-chain management. For instance, the performance of ESG interacts with supply-chain operation management (Dai and Tang, 2022) [18]. Strengthening corporate governance can enhance supply-chain productivity (Ziolo et al., 2019) [19]. Increasing the awareness of environmental performance proves beneficial for companies to actively engage in sustainable development initiatives (Sardanelle et al., 2022) [20]. However, most of the literature focuses on examining ESG performance as a measure of supply-chain sustainability (Rajesh, 2020) [21]. Li et al., (2021) employed CiteSpace analysis to explore the frequency of occurrence of ESG-related keywords in green supply-chain performance research, revealing a limited amount of relevant studies on ESG [22]. Hence, this study aims to investigate the relationship between the green supply-chain performance and ESG, filling the research gap. Among these factors, the term "environment" refers to the efforts made by a company to improve its environmental performance and reduce the negative impact of its products and operations on the environment. Green-product innovation can promote environmental protection and sustainable development, corresponding to the environmental aspect of ESG performance. Social aspects mainly refer to the specific behavioral manifestations of a company's balance and coordination with stakeholders during the process of economic development. Supply-chain collaboration involves the relationships and interactions between a company and its suppliers and partners, requiring coordination and cooperation in various aspects to generate social benefits, corresponding to social performance. Governance reflects the independence, experience, and diversification of a company's management. Supply-chain risks and supply-chain management capabilities are related to a company's governance mechanism and risk-management ability, corresponding to the corporate governance aspect of ESG performance.

Companies seek ways to enhance supply-chain resilience and performance in three aspects: environment, social, and corporate governance. At the same time, scholars have differing views on whether new technologies, such as artificial intelligence, can promote improvements in supply-chain performance. Some scholars argue that new technologies can enhance production efficiency and product quality, assisting companies in making accurate predictions (Soni et al., 2020) [23] and better understanding and addressing risks and uncertainties in the supply chain. They can also help companies achieve and maintain various competitive advantages (Albert-Morant et al., 2016) [24], resulting in cost benefits but also profitability (Chan et al., 2016) [25]. However, some scholars believe that technologies like artificial intelligence have inherent risks and vulnerabilities, and many individuals cannot fully trust the recommendations provided by these technologies [26]. In conclusion, different scholars hold different opinions regarding new technology adoption.

In light of this aforementioned context, this study constructs a model of the relationships between various factors that influence supply-chain resilience and performance. It explores factors that affect supply-chain resilience and performance from the perspectives of society, environment, and governance. It investigates the positive mediating role of willingness to adopt new technologies. The aim is to expand the research field of ESG about green supply-chains, enrich the relevant theories, and provide guidance for enhancing green supply-chain performance in the context of environmental uncertainty.

The structure of this paper is as follows: Section 2 presents the research status of supply-chain collaboration, supply-chain management capabilities, green-product innovation, supply-chain risks, the willingness to adopt new technologies, supply-chain resilience, and supply-chain performance. It also derives assumptions regarding their interrelationships and proposes the research hypotheses and the model of this paper. Sections 3 and 4 outline the research design, where questionnaires were distributed to company managers, and the collected data were analyzed and summarized. Finally, Section 5 provides a detailed discussion of the research findings, highlights the limitations of this paper, and suggests future directions for further exploration.

## 2. Literature Review and Hypotheses

### *2.1. Supply-Chain Collaboration and New Technology Adoption Intention*

Supply-chain collaboration refers to the cooperation among enterprises in the supply chain through methods such as information sharing, risk sharing, and profit sharing, making full use of internet technology and e-commerce means to collaboratively optimize operations and improve efficiency, thereby achieving higher profits. It is a fundamental area in supply-chain research, as collaboration facilitates cooperation among members along the supply-chain and can improve performance (Bowersox, 1990) [27], in which information technology (IT) plays a crucial role, allowing companies to achieve goals that individuals cannot achieve through the sharing and coordination of internal and external resources [28]. The advancement of information technology and the rapid development of new technologies can greatly transform supply-chain collaboration, agility, and the overall performance of companies and supply chains (Wang et al., 2017; Alzoubi and Yanamandra, 2020; Baah et al., 2021) [29–31]. Some of these new technologies include the Internet of Things, big data analytics, artificial intelligence, among others. These technologies can be used for tracking logistics, optimizing inventory management, predicting demand, improving production planning, and ultimately enhancing the efficiency and responsiveness of the supply chain. Moreover, the adoption of new technologies can strengthen the collaborative cooperation among different nodes in the supply chain, achieving the goals of information sharing, risk sharing, resource sharing, and ultimately improving the overall performance of the entire supply chain. Therefore, this article assumes that:

**H1.** *Supply-Chain collaboration has a significant positive impact on the intention to adopt new technologies.*

**H2.** *The adoption intention of new technologies mediates the relationship between supply-chain collaboration and supply-Chain resilience/performance.*

### *2.2. Supply-Chain Management Capabilities and New Technology Adoption Intention*

In the context of an increasingly fierce external environment, competition is no longer confined to individual enterprises but manifests as competition among supply chains. In this scenario, companies situated at the core of the supply chain must not only emphasize the cultivation of their capabilities but also prioritize the enhancement of their supply-chain management capabilities (Krasnikov and Jayachandran (2008)) [32]. Supply-chain management capability involves the integration of operations among suppliers, manufacturing firms, distributors, and customers, reducing costs and reducing response times to customers (Sabry, 2015) [33]. It enables the efficient conversion of tangible or intangible resources into products or services that cater to customer needs (Ramaswami, Srivastava and Bhargava (2009); Fang and Zou (2009)) [34,35]. These products or services are then delivered to them through processes such as procurement, production, and transportation. Supply-chain management capability pertains to the ability to plan, coordinate, and control the flow of logistics, information, and capital among the organizations involved in the supply chain. It maximizes operational efficiency at each stage, striking a balance between speed and stability, thereby maximizing net value-added for companies along the supply chain [36]. The adoption of new technologies not only enhances supply-chain management efficiency but also makes the process more flexible and transparent. Furthermore, it improves supply-chain management reliability and responsiveness. For instance, blockchain technology enables the secure storage and sharing of supply-chain information, ensuring its authenticity and integrity and reducing information asymmetry. Cloud computing technology enables the remote access and management of supply-chain information, enhancing supply-chain management flexibility and scalability. Big data technology allows for rapid analysis and response to supply-chain information, thereby improving supply-chain management responsiveness and decision-making capabilities. By leveraging new technologies to enhance supply-chain management flexibility and responsiveness, companies can optimize and upgrade their supply chains. This will improve their competitiveness and market share. Therefore, this article assumes that:

**H3.** *Supply-chain management capability has a significant positive impact on the adoption intention of new technologies.*

**H4.** *The adoption intention of new technologies plays a mediating role between supply-chain management capability and supply-chain resilience/performance.*

### *2.3. Green-Product Innovation and New Technology Adoption Intention*

As environmental issues have become increasingly prominent, green technology innovation capability has been the focus of sustained attention from the business sector (Abdullah, Zailani, Iranmanesh, and Jayaraman, 2016) [37], especially for manufacturing enterprises, which have a responsibility to shoulder environmental protection. Green technology innovation is committed to pursuing a development pattern of "win-win" between the environment and the economy and is considered a key factor in addressing environmental problems (Kong, Feng, and Ye, 2016) [38]. Furthermore, it is also one of the main sources for enterprises to improve their competitive advantage (AlbortMorant, Leal-Millán, and Cepeda-Carrión, 2016) [24]. Green-technology innovation can be divided into two categories: green-product innovation and green process innovation [39]. When studying green-technology innovation, it is common to consider the impact of several different types of innovation capabilities (such as the cumulative effects of product innovation capabilities and process innovation capabilities) on performance. This article specifically investigates the impact of green-product innovation on supply-chain performance under the adoption of new technologies. Green-product innovation refers to the process of incorporating environmental concepts into various stages of the product life cycle, such as design, manufacturing, and marketing, to make it significantly more innovative and environmentally friendly than other conventional or competing products. According to Luo Jian (2011), the purpose of product innovation is to respond to customers' demand for new products or to meet the expectations of managers to access new markets [40]. Product innovation can help organizations differentiate their products and respond to changes in their external environment. Green-product innovation reduces negative environmental impacts on enterprises and improves their profitability by reducing waste and costs (Singh et al., 2020) [41]. The development of new technologies can promote product innovation in enterprises. Therefore, this article assumes that:

**H5.** *Green-product innovation has a significant positive impact on the adoption intention of new technologies.*

**H6.** *The adoption intention of new technologies plays a mediating role between green-product innovation and supply-chain resilience/performance.*

### *2.4. Supply-Chain Risk and New Technology Adoption Intention*

Early supply-chain management primarily focused on problem research in deterministic environments, such as studies on supplier selection and evaluation, logistics network design and optimization, collaboration among supply-chain nodes, contract and benefit allocation mechanisms, strategic alliances, and other related issues [42]. However, with the accelerated process of globalization and the increasing uncertainty and complexity of the environment, the probability of supply-chain disruptions has significantly increased. Moreover, the theoretical research on chains in deterministic environments has limited practical guidance for industries and companies [43]. Christopher et al., (2014) pointed out that trends such as leaner and more agile supply chains in the past decade have made supply chains more vulnerable, and supply-chain risk has gradually become the focus of supply-chain research (Hohenstein et al., 2015; Ali et al., 2017) [44,45]. Based on scholars' definitions of supply-chain risk, this study considers supply-chain risk as the magnitude and likelihood of deviations between the actual and expected benefits of supply-chain enterprises in their operational processes due to various uncertain factors. In response to the vulnerability of supply-chains in the face of unforeseen events, many scholars and experts have turned their attention to resilient supply chains, aiming to quickly recover from disruptions by enhancing the resilience of the supply chain. New technologies are one of the important means to improve supply-chain resilience and reduce supply-chain risks. Technologies such as artificial intelligence enable the intelligent analysis and forecasting of supply-chain information, assisting enterprises in better grasping market changes and demand trends, thereby enhancing the ability to manage supply-chain risks. Through the use of technologies such as the Internet of Things, cloud computing, and big data, the visualization, automation, and intelligence of supply-chain management can be achieved, enabling faster and more accurate responses to market demands and changes. Therefore, the adoption of new technologies can reduce supply-chain risks and enhance the resilience and robustness of the supply-chain. This paper assumes that:

**H7.** *Supply-Chain risk has a significant positive impact on the adoption intention of new technologies.*

**H8.** *The adoption intention of new technologies plays a mediating role between supply-chain risk and supply-Chain resilience/performance.*

### *2.5. New Technology Adoption Intention and Supply-Chain Resilience/Performance*

The majority of scholars consider supply-chain resilience as the ability to respond to disruptions and interruptions (Falasca et al., 2008; Ponomarov and Holcomb, 2009) [12,46]. Falasca et al., (2008) include in their definition the probability of disruptions or interruptions, and the consequences of such disruptions, as well as response and recovery time [12]. Ponomarov and Holcomb (2009) consider significant factors such as adaptability, unexpected events, response and recovery capabilities, and control over the structure [46]. Existing research on supply-chain resilience focuses on the prevention, response, and recovery stages of supply-chain disruptions (Chowdhury and Quaddus, 2016) [47], with an emphasis on exploring measures of resilience, strategies, and supply performance (Tukamuhabwa et al., 2015; Sahebjamnia, 2018) [48,49]. Research on supply-chain resilience and performance has found that enhancing sustainable capacity and resilience in the chain contributes to improving supply-chain (firm) performance (Liu et al., 2018; Gunessee et al., 2018) [50,51]. Empirical evidence, as demonstrated by Li et al., (2017) and others, is gained by examining the impact of supply-chain resilience dimensions on firms' financial performance [52]. By establishing supply-chain resilience, companies can effectively mitigate disruption threats and recover to their original operational level or achieve an even better state within a certain timeframe, thereby improving relationships among supply-chain partners (Soni et al., 2014) and enhancing supply-chain performance [53]. Gunasekaran et al., (2001) argue that supply-chain performance should be evaluated based on manufacturing and inventory costs, responsiveness to changes in delivery requirements, and integration with partners [54]. Based on these descriptions, we define supply-chain performance by its flexibility, integration, and customer responsiveness. The adoption of new technologies better assists companies in establishing supply-chain resilience, enabling them to address the instability and complexity of the environment, and respond swiftly to the market, thereby enhancing supply-chain performance. Therefore, this article assumes that:

**H9.** *The adoption intention of new technologies has a significant positive impact on the supply-chain resilience.*

**H10.** *The adoption intention of new technologies has a significant positive impact on the supply-chain performance.*

**H11.** *The supply-chain resilience has a significant positive impact on the supply-chain performance.*

As mentioned above, the research model in this paper is depicted in Figure 1.

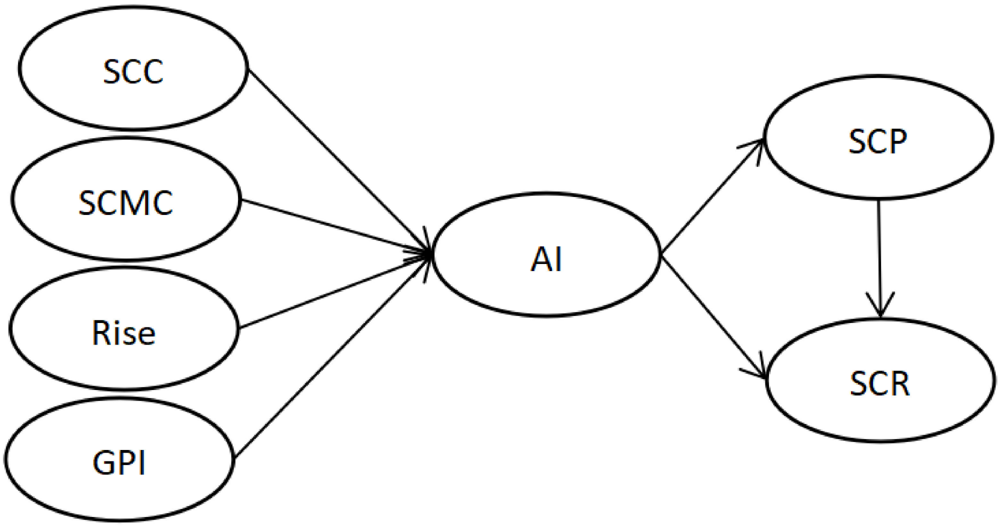


**Figure 1.** The research model. NOTE: supply-chain collaboration (SCC); supply-chain management capabilities (SCMC); green-product innovation (GPI); supply-chain risk (Risk); adopt intention (AI); supply-chain performance (SCP); supply-chain resilience (SCR).

## 3. Methodology

### *3.1. Sampling and Data Collection*

In the theoretical framework proposed in this study, the concepts used are not directly observable or measurable. Furthermore, there are complex causal and interaction relationships in supply-chain research. Therefore, this paper chooses Structural Equation Modeling (SEM) as the analytical tool. SEM can be used to construct complex relationships between multiple latent variables. It allows observed variables and measurement errors in the model. Through SEM, it is possible to analyze the causal relationships among various elements in the supply chain and explore their impact on overall performance.

In order to ensure the reliability and validity of the measurement instrument employed, this study drew upon a wide range of measurement tools utilized by scholars both domestically and internationally to construct the initial measurement instrument for this paper. However, due to the cultural differences between China and Western countries, it was necessary to revise the measurement instrument to align with Chinese language conventions and cultural background. Further semantic revisions were made by engaging with multiple respondents to ensure accuracy. Finally, a small-scale survey was conducted. Through the aforementioned steps and the analysis of the small sample data, the final survey questionnaire was determined.

This study targeted middle and senior managers (responsible for the operation of various departments in the industry) of enterprises as the survey subjects. The questionnaire was distributed through scientific research institutions, MBA learning platforms of universities, and email. After eliminating unqualified questionnaires with too many missing responses, a total of 349 valid questionnaires were collected, with an effective response rate of 69.5%. Among them, 61.3% of the survey respondents were male and 38.7% were female. In terms of industry distribution, 5.1% were in the information and communication industry, 21.1% were in the service industry, 10.0% were in the manufacturing industry, 47.4% were in the trade and distribution industry, and 16.5% were in the logistics and transportation industry.

### *3.2. Measurement of Variables*

The present study utilized a Likert 5-point scale to measure responses to the survey items, where 1 represents "completely disagree" and 5 represents "completely agree".

## 4. Data Analysis and Results

### *4.1. Reliability Analysis and Validity Analysis*

The variables were subjected to reliability and validity tests using SPSS 23.0 and AMOS 26.0, and the results are presented in Table 1. Cronbach's $\alpha$ coefficients for all variables exceeded 0.7, indicating high internal consistency and the good reliability of the scale. Confirmatory factor analysis (CFA) yielded the following results: $\chi^2/df = 1.078$, RMSEA = 0.015, GFI = 0.947, CFI = 0.996, NFI = 0.944, TLI = 0.995. All fit indices met the criteria for good fit. Furthermore, all factor loadings exceeded 0.7, and the composite reliabilities (CR) were all above 0.7, indicating the satisfactory convergent and discriminant validity of the scale. The average variance extracted (AVE) for each variable exceeded 0.5, and the correlation coefficients between factors were smaller than the square root of AVE (see Table 2), demonstrating good discriminant validity of the scale. In conclusion, the scale exhibited good validity and reliability.

**Table 1.** Measurement of variables.

| The Variable | Measurement Dimension | Reference |
|---|---|---|
| Supply-chain collaboration | "Information sharing", "Decision synchronization", "Incentive alignment". | Simatupang and Sridharan (2004) [55] |
| Supply-chain management capabilities | "Outward-in process capability", "Inward-out process capability", "Cross-process capability". | Sabry (2015) [33] |
| Green-product innovation | "Using less or non-polluting/toxic materials", "Improving and designing environmentally friendly packaging", "Recovery of company end-of-life products and recycling", "Using eco-labeling". | Chen et al., (2006); Chen (2008); Chiou et al., (2011) [56–58] |
| Supply-chain risk | "Supply risk", "operational risk", "demand risk", "security risk". | Manuj and Mentzer (2008) [59] |
| Adopt intention | "Willingness to Use", "Willingness to Pay", "Willingness to Recommend". | Davis (1989); Venkatesh et al., (2003); Venkatesh and Zhang (2010) [60–62] |
| Supply-chain resilience | "Absorption capacity", "recovery capacity", "adaption capacity". | Pettit et al., (2013) [63] |
| Supply-chain performance | "Resource measurement", "output measurement", "flexibility". | Beamon (1999) [64] |

**Table 2.** Reliability and validity statistics.

| Construct | Code | Loadings | Cronbach's Alpha | AVE (Average Variance Extracted) | CR (Composite Reliability) |
|---|---|---|---|---|---|
| GPI | GPI3 | 0.833 | 0.854 | 0.599 | 0.856 |
| | GPI4 | 0.782 | | | |
| | GPI2 | 0.77 | | | |
| | GPI1 | 0.765 | | | |
| Risk | Risk3 | 0.824 | 0.832 | 0.562 | 0.836 |
| | Risk1 | 0.802 | | | |
| | Risk2 | 0.739 | | | |
| | Risk4 | 0.696 | | | |
| SCC | SCC3 | 0.875 | 0.897 | 0.745 | 0.898 |
| | SCC1 | 0.86 | | | |
| | SCC2 | 0.858 | | | |
| SCMC | SCMC3 | 0.825 | 0.809 | 0.586 | 0.809 |
| | SCMC1 | 0.821 | | | |
| | SCMC2 | 0.798 | | | |
| SCP | SCP3 | 0.786 | 0.802 | 0.576 | 0.803 |
| | SCP1 | 0.763 | | | |
| | SCP2 | 0.756 | | | |
| AI | SCR3 | 0.782 | 0.793 | 0.561 | 0.793 |
| | SCR2 | 0.728 | | | |
| | SCR1 | 0.713 | | | |
| SCR | AI1 | 0.797 | 0.801 | 0.574 | 0.802 |
| | AI3 | 0.721 | | | |
| | AI2 | 0.655 | | | |
| Kaiser–Meyer–Olkin Measure of Sampling Adequacy. | | | | | 0.895 |
| Bartlett's Test of Sphericity | | | | Approx. Chi-Square | 3911.907 |
| | | | | df | 253 |
| | | | | Sig. | 0.000 |

### 4.2. Correlation Analysis

According to the Fornell–Larker Criterion, AVE's square root on diagonal values should be greater than the corresponding correlations' values. This study meets the criteria, as shown in Table 3.

**Table 3.** Latent variable correlation and square root of AVE.

| | SCMC | SCC | Risk | GPI | AI | SCP | SCR |
|---|---|---|---|---|---|---|---|
| SCMC | 0.861 | | | | | | |
| SCC | 0.267 ** | 0.757 | | | | | |
| Risk | 0.195 ** | 0.282 ** | 0.752 | | | | |
| GPI | 0.208 ** | 0.359 ** | 0.256 ** | 0.785 | | | |
| AI | 0.379 ** | 0.399 ** | 0.527 ** | 0.429 ** | 0.760 | | |
| SCP | 0.414 ** | 0.393 ** | 0.384 ** | 0.408 ** | 0.327 ** | 0.778 | |
| SCR | 0.333 ** | 0.312 ** | 0.489 ** | 0.476 ** | 0.515 ** | 0.452 ** | 0.771 |

Note: All correlations with absolute values greater than 0.110 are statistically significant at $p < 0.05$. Values in italicized bold denote the square root of the AVE of each construct. ** Correlation is significant at the 0.01 level (2-tailed).

*4.3. Hypothesis Test*

When examining the relationship between supply-chain resilience and performance, we utilized structural equation modeling analysis with AMOS23.0 to model the data. This allowed us to compute standardized regression coefficients (path coefficients) and evaluate their statistical significance, facilitating a better understanding of the causal relationships among the variables. Moreover, we generated a path diagram to illustrate the interplay among the variables. Results are shown as follows in Figure 2.

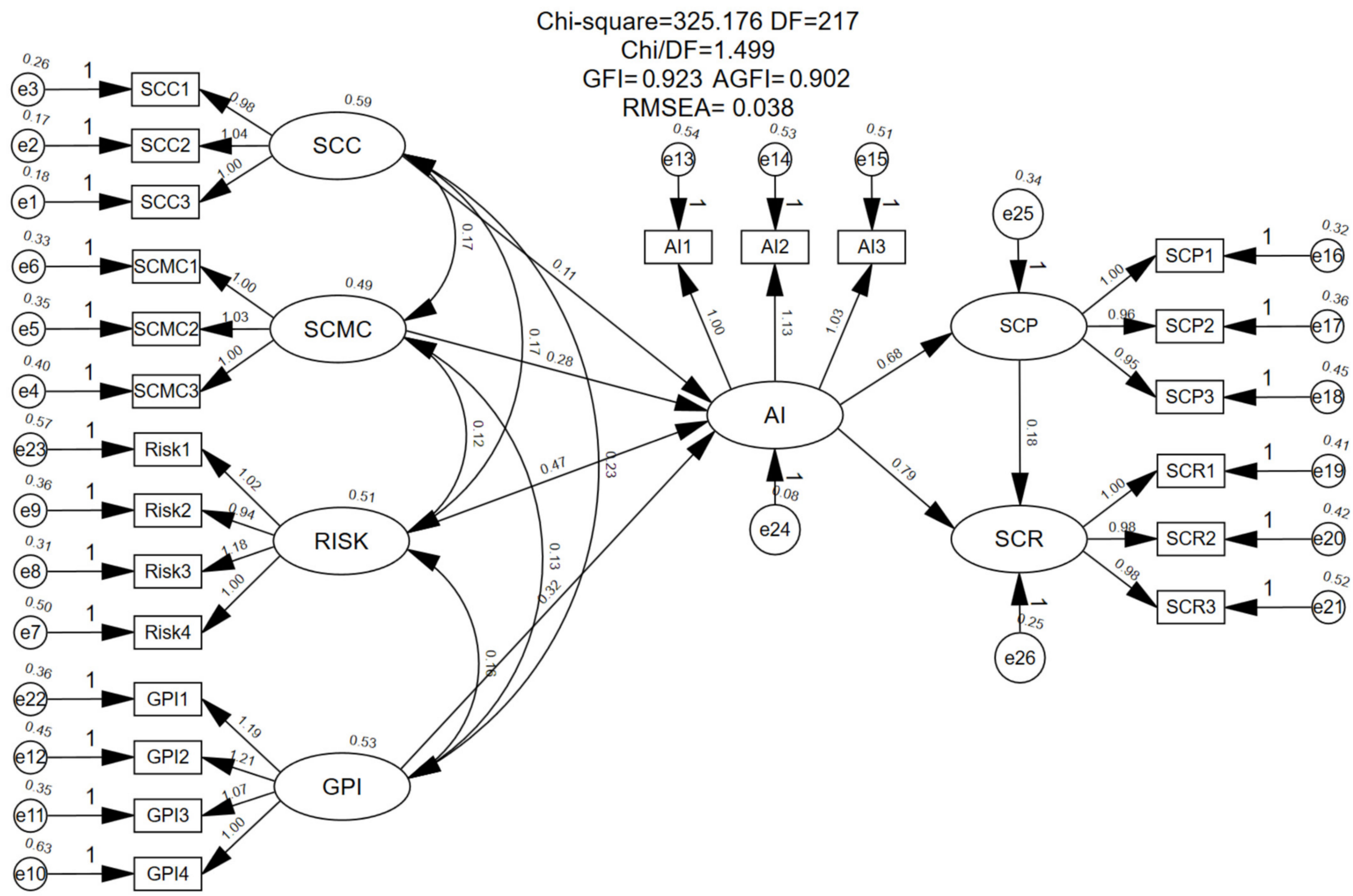


**Figure 2.** Structural model analysis results.

After the establishment of the structural equation model, this study adopted AMOS 23.0 to test the goodness of fit between the model and the data. After analyzing the characteristics of the fitting index, this study selected the following seven fit indexes to test the model (as shown in Table 4).

**Table 4.** Comparison between fitting results and ideal results of model and data.

| The Revised Index | CMIN/DF | GFI | AGFI | CFI | NFI | TLI | RMSEA |
|---|---|---|---|---|---|---|---|
| Ideal results | <3 and >1 | >0.8 | >0.8 | >0.9 | >0.9 | >0.9 | <0.08 |
| The fitting results | 1.499 | 0.923 | 0.902 | 0.971 | 0.919 | 0.966 | 0.038 |

Model Hypothesis Testing: In this study, structural equation modeling was conducted using AMOS 26.0. The maximum likelihood estimation method was employed to obtain path regression coefficients for validating the proposed seven hypotheses. The analysis results indicate that all seven paths in the structural equation were statistically significant, and the significance tests for each path met the standard requirements ($p \leq 0.05$) (as shown in Table 5). Specifically, Hypotheses 1, 3, 5, 7, 9, 10, and 11 were validated.

**Table 5.** Structural equation—AMOS model path analysis results.

| | Estimate | S.E. | C.R. | *p* | Hypothesis | Conclusion |
|---|---|---|---|---|---|---|
| SCC → AI | 0.114 | 0.042 | 2.692 | 0.007 ** | H1 | Support |
| SCMC → AI | 0.283 | 0.05 | 5.703 | *** | H3 | Support |
| Risk → AI | 0.398 | 0.045 | 8.763 | *** | H5 | Support |
| GPI → AI | 0.317 | 0.051 | 6.191 | *** | H7 | Support |
| AI → SCP | 0.677 | 0.079 | 8.518 | *** | H9 | Support |
| AI → SCR | 0.787 | 0.101 | 7.793 | *** | H10 | Support |
| SCP → SCR | 0.179 | 0.077 | 2.324 | 0.02 * | H11 | Support |

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

### 4.4. Mediating Effect Analysis

In order to further investigate the role of willingness to adopt new technologies, the present study employed the bootstrapping method to examine the mediating effects. According to the standard for testing, if the confidence interval does not include 0 at a confidence level of 95%, then the mediating path exists (Preacher and Hayes, 2004, 2008) [65,66]. The results are shown in Table 6. Therefore, the mediating Hypotheses H2, H4, H6, and H8 are significant.

**Table 6.** Mediation effect results.

| Path | Effects | Boot SE | Bia-Corrected 95%CI | | Hypothesis | Results |
|---|---|---|---|---|---|---|
| | | | Lower | Upper | | |
| SCC → AI → SCR | 0.077 | 0.03 | 0.02 | 0.14 | H2 | Support |
| SCMC → AI → SCR | 0.191 | 0.042 | 0.117 | 0.285 | H4 | Support |
| Risk → AI → SCR | 0.269 | 0.04 | 0.193 | 0.351 | H6 | Support |
| GPI → AI → SCR | 0.215 | 0.046 | 0.131 | 0.313 | H8 | Support |
| SCC → AI → SCP | 0.104 | 0.039 | 0.025 | 0.18 | H2 | Support |
| SCMC → AI → SCP | 0.257 | 0.046 | 0.174 | 0.356 | H4 | Support |
| Risk → AI → SCP | 0.362 | 0.043 | 0.283 | 0.453 | H6 | Support |
| GPI → AI → SCP | 0.288 | 0.054 | 0.186 | 0.398 | H8 | Support |

## 5. Discussion and Conclusions

During the unstable period of the post-pandemic environment, the supply-chain performance of many enterprises has declined, resulting in stagnation in development. To overcome economic challenges and enhance supply-chain performance, the adoption of green innovation technologies and the improvement in corporate ESG performance have become crucial pathways for business growth. This article systematically reviewed the relevant studies on supply chains and, starting from ESG performance, categorized the factors influencing the supply-chain system into three aspects: environmental, social, and governance, thereby expanding the application scope of ESG. Through empirical analysis of enterprises, this study examined the reasons for adopting new technologies from four perspectives: supply-chain collaboration, supply-chain management capabilities, supply-chain risks, and green-product innovation. Furthermore, it confirms the positive impact of the willingness to adopt new technologies on the supply-chain resilience and performance of enterprises, providing new insights for green supply-chain research.

*5.1. Conclusions*

Supply-chain collaboration, supply-chain management capabilities, supply-chain risks, and green-product innovation all have positive impacts on the adoption intention of new technologies, with supply-chain risks exerting the most significant influence (β = 0.398). Specifically, supply-chain collaboration provides opportunities for information sharing, resource sharing, and collaborative innovation, thereby enhancing the acceptance and adoption intention of new technologies by enterprises. Simultaneously, outstanding supply-chain management capabilities improve the transparency, efficiency, and collaborative abilities of the supply-chain, enabling enterprises to better understand and apply new technologies. Furthermore, supply-chain risks directly threaten the survival and development of businesses, compelling them to actively adopt new technologies to mitigate risks and enhance the resilience of their supply chain. Green-product innovation inspires the demand and interest of enterprises in new technologies, thus driving their adoption. Despite all these factors having positive influences on the adoption intention of new technologies, the impact of supply-chain risks is particularly notable, possibly due to their direct threats to the survival and development of enterprises, prompting them to actively adopt new technologies to reduce risks and enhance the flexibility of the supply chain. These research findings provide important insights for businesses, emphasizing the significance of prioritizing supply-chain collaboration, enhancing supply-chain management capabilities, mitigating supply-chain risks, and strengthening green-product innovation to promote the adoption of new technologies, achieve sustained innovation, and gain competitive advantages.

The willingness to adopt new technologies has a significant positive impact on the resilience and performance of the supply-chain, with the most pronounced effect on supply-chain performance (β = 0.787). The willingness to adopt new technologies can drive the flexibility of the supply-chain, enabling businesses to be more adaptable and agile in response to market changes and demand fluctuations. Through the application of digital, intelligent, and automated technologies, companies can achieve rapid resource allocation and adjustments in supply-chain processes to meet customer demands. Simultaneously, the willingness to adopt new technologies can significantly enhance the performance level of the supply chain. By optimizing production processes, and conducting real-time data analysis and forecasting, companies can achieve efficient demand prediction and inventory management, thereby reducing resource waste and time delays while improving on-time delivery rates and customer satisfaction. Therefore, companies should actively promote the introduction and application of new technologies to enhance the resilience and performance level of the supply-chain, thus achieving competitive advantages and sustainable development. This holds significant strategic significance for businesses.

Supply-chain resilience has a significant positive impact on enhancing supply-chain performance (β = 0.179). A resilient supply-chain enables enterprises to better cope with market changes, demand fluctuations, and uncertainties. Through flexible resource allocation and rapid adjustments in supply-chain processes, enterprises can reduce production and delivery lead times, decrease inventory costs, and enhance customer satisfaction. A resilient supply-chain is better equipped to handle risks and disruptions within the supply-chain, ensuring business continuity and possessing higher adaptability and risk-mitigation capabilities. Therefore, supply-chain resilience plays a crucial role in improving supply-chain performance.

The adoption intention of new technologies plays a positive mediating role in enhancing supply-chain performance. Supply-chain collaboration, supply-chain management capability, supply-chain risk, and green-product innovation have a positive impact on supply-chain resilience through the adoption intention of new technologies (β values of 0.077, 0.191, 0.269, and 0.215, respectively). Additionally, supply-chain collaboration, supply-chain management capability, supply-chain risk, and green-product innovation positively contribute to the improvement in supply-chain performance through the adoption intention of new technologies (β values of 0.104, 0.257, 0.362, and 0.288, respectively).

Notably, the adoption intention of new technologies plays a crucial mediating role between supply-chain risk and supply-chain performance, with the highest proportion of the total effect. By introducing advanced technological tools and systems, enterprises can better monitor and manage various risks in the supply chain, such as supply disruptions, quality issues, and logistical delays. The application of new technologies provides more accurate and real-time data, enabling companies to identify and assess potential risks more precisely and take appropriate preventive measures. Therefore, the adoption of new technologies has a direct and significant impact on reducing supply-chain risks.

### *5.2. Implications*

Based on this, the specific implications for businesses are as follows:

Prioritizing Supply-chain risk management: For businesses, it is essential to emphasize supply-chain risk management. As the risks associated with the supply chain increase, there is a greater need to adopt new technologies to address these challenges. By implementing new technologies to establish risk monitoring systems, companies can more swiftly detect and respond to potential supply-chain risks, enhancing the resilience and response capabilities of their supply chains. Furthermore, new technologies can assist companies in effectively managing risks associated with suppliers and supply-chain partners, ensuring the stability and reliability of the supply chain. In the face of ever-changing markets and competitive environments, as well as supply-chain risks, the adoption of new technologies proves to be an effective approach to improving the flexibility and responsiveness of businesses' supply chains.

Enhancing supply-chain collaboration and management capabilities: Companies should actively promote collaboration and communication among various stakeholders in the supply chain, fostering stable cooperative relationships to jointly drive the application and development of new technologies. Simultaneously, optimizing supply-chain management capabilities to improve transparency and efficiency while reducing costs enables companies to generate additional funding and resources, providing necessary support for the development of new technologies. Furthermore, through the adoption of new technologies, businesses can facilitate internal digitalization and information transformation, further strengthening communication and collaboration with suppliers, customers, and other partners, optimizing supply-chain layout and resource allocation.

Promoting green-product innovation and establishing a green supply-chain system: Green-product innovation helps businesses enhance product value and brand image, creating more profits and commercial value. It stimulates companies' demand and interest in new technologies, encouraging the increased investment in technological innovation and further driving their willingness to adopt new technologies, leading to a virtuous cycle of sustainable development. Therefore, companies should increase their investment and research, and development in green-product innovation to meet the growing environmental requirements and consumer demands. Simultaneously, they should also strengthen the study and application of new technologies to achieve more environmentally friendly and sustainable production methods, thereby further improving their competitiveness and market share.

In summary, businesses should comprehensively consider factors such as supply-chain collaboration, supply-chain management capabilities, supply-chain risks, and green-product innovation. The willingness to adopt new technologies serves as a key mediating variable in enhancing the resilience and performance of the supply chain. These measures contribute to improving competitiveness, adapting to market changes, and achieving sustainable development and long-term growth.

### *5.3. Research Limitations and Future Research*

While providing new insights for practical application in enterprises, this article also has some limitations. Firstly, due to constraints in terms of time, energy, and resources, this study focuses solely on companies within the Chinese region and represents only a limited number of industries. To enhance the generalizability of the research, future studies can include classification research on enterprises in other regions, such as comparative analyses between developing and developed countries, or comparative studies on companies at different stages of development within the same country. Furthermore, the research perspective in this article is not comprehensive enough as it solely focused on the internal factors influencing supply-chain performance in enterprises, while neglecting certain external factors such as politics and culture. Therefore, future studies should comprehensively consider the factors influencing supply-chain performance from multiple perspectives.

**Author Contributions:** Designed the study: W.L. and Z.L.; conducted the data analysis: W.L.; provided the mathematical methods: Z.L.; drafted the paper: W.L.; edited the paper: W.L. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** This study did not report any data.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References


1. Kleindorfer, P.R.; Saad, G.H. Managing disruption risks in supply chains. *Prod. Oper. Manag.* **2005**, *14*, 53–68. [CrossRef]
2. Speier, C.; Whipple, J.M.; Closs, D.J.; Voss, M.D. Global supply chain design considerations: Mitigating product safety and security risks. *J. Oper. Manag.* **2011**, *29*, 721–736. [CrossRef]
3. Knemeyer, A.M.; Zinn, W.; Eroglu, C. Proactive planning for catastrophic events in supply chains. *J. Oper. Manag.* **2009**, *27*, 141–153. [CrossRef]
4. Zhang, N.; Liu, C. Enterprise collaborative emergency strategies for responding to supply chain unexpected events risks. *Bus. Econ. Manag.* **2011**, *3*, 17–23.
5. Spieske, A.; Birkel, H. Improving supply chain resilience through industry 4.0: A systematic literature review under the impressions of the COVID-19 pandemic. *Comput. Ind. Eng.* **2021**, *158*, 107452. [CrossRef]
6. Grzybowska, K.; Tubis, A.A. Supply Chain Resilience in Reality VUCA—An International Delphi Study. *Sustainability* **2022**, *14*, 10711. [CrossRef]
7. Chen, J.K.; Huang, T.Y. The Multi-Level Hierarchical Structure of the Enablers for Supply Chain Resilience Using Cloud Model-DEMATEL–ISM Method. *Sustainability* **2022**, *14*, 12116. [CrossRef]
8. Lockamy, A., III; McCormack, K. Analysing risks in supply networks to facilitate outsourcing decisions. *Int. J. Prod. Res.* **2010**, *48*, 593–611. [CrossRef]
9. Heckmann, I.; Comes, T.; Nickel, S. A critical review on supply chain risk–Definition, measure and modeling. *Omega* **2015**, *52*, 119–132. [CrossRef]
10. Svensson, G. A conceptual framework for the analysis of vulnerability in supply chains. *Int. J. Phys. Distrib. Logist. Manag.* **2000**, *30*, 731–750. [CrossRef]
11. Pettit, T.J.; Fiksel, J.; Croxton, K.L. Ensuring supply chain resilience: Development of a conceptual framework. *J. Bus. Logist.* **2010**, *31*, 1–21. [CrossRef]
12. Falasca, M.; Zobel, C.W.; Cook, D. A decision support framework to assess supply chain resilience. In Proceedings of the 5th International ISCRAM Conference, Washington, DC, USA, 4 May 2008; pp. 596–605.
13. Jüttner, U.; Maklan, S. Supply chain resilience in the global financial crisis: An empirical study. *Supply Chain Manag. Int. J.* **2011**, *16*, 246–259. [CrossRef]
14. Peck, H. Drivers of supply chain vulnerability: An integrated framework. *Int. J. Phys. Distrib. Logist. Manag.* **2005**, *35*, 210–232. [CrossRef]
15. Stewart, M.; Reid, G.; Mangham, C. Fostering children's resilience. *J. Pediatr. Nurs.* **1997**, *12*, 21–31. [CrossRef] [PubMed]
16. Arsovski, S.; Arsovski, Z.; Stefanović, M.; Tadić, D.; Aleksić, A. Organisational resilience in a cloud-based enterprise in a supply chain: A challenge for innovative SMEs. *Int. J. Comput. Integr. Manuf.* **2017**, *30*, 409–419. [CrossRef]
17. Atkins, B. *Demystifying ESG: Its History & Current Status*; Forbes Markets: Jersey City, NJ, USA, 2020.
18. Dai, T.; Tang, C. Frontiers in Service Science: Integrating ESG Measures and Supply Chain Management: Research Opportunities in the Postpandemic Era. *Serv. Sci.* **2022**, *14*, 1–12. [CrossRef]
19. Ziolo, M.; Filipiak, B.Z.; Bąk, I.; Cheba, K. How to design more sustainable financial systems: The roles of environmental, social, and governance factors in the decision-making process. *Sustainability* **2019**, *11*, 5604. [CrossRef]
20. Sardanelli, D.; Bittucci, L.; Mirone, F.; Marzioni, S. An integrative framework for supply chain rating: From financial-based to ESG-based rating models. *Total Qual. Manag. Bus. Excell.* **2022**, *20*, 69557. [CrossRef]

21. Rajesh, R. Exploring the sustainability performances of firms using environmental, social, and governance scores. *J. Clean. Prod.* **2020**, *247*, 119600. [CrossRef]
22. Li, T.T.; Wang, K.; Sueyoshi, T.; Wang, D.D. ESG: Research progress and future prospects. *Sustainability* **2021**, *13*, 11663. [CrossRef]
23. Soni, N.; Sharma, E.K.; Singh, N.; Kapoor, A. Artificial intelligence in business: From research and innovation to market deployment. *Procedia Comput. Sci.* **2020**, *167*, 2200–2210. [CrossRef]
24. Albort-Morant, G.; Leal-Millán, A.; Cepeda-Carrión, G. The antecedents of green innovation performance: A model of learning and capabilities. *J. Bus. Res.* **2016**, *69*, 4912–4917. [CrossRef]
25. Chan, H.K.; Yee, R.W.; Dai, J.; Lim, M.K. The moderating effect of environmental dynamism on green product innovation and performance. *Int. J. Prod. Econ.* **2016**, *181*, 384–391. [CrossRef]
26. Kaplan, A.; Haenlein, M. Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Bus. Horiz.* **2019**, *62*, 15–25. [CrossRef]
27. Bowersox, D.J. The strategic benefits of logistics alliances. *Harv. Bus. Rev.* **1990**, *68*, 36–43.
28. McIvor, R.; Humphreys, P.; McCurry, L. Electronic commerce: Supporting collaboration in the supply chain. *J. Mater. Process. Technol.* **2003**, *139*, 147–152. [CrossRef]
29. Zhong, R.; Xu, X.; Wang, L. Food supply chain management: Systems, implementations, and future research. *Ind. Manag. Data Syst.* **2017**, *17*, 2085–2114. [CrossRef]
30. Alzoubi, H.M.; Yanamandra, R. Investigating the mediating role of information sharing strategy on agile supply chain. *Uncertain Supply Chain Manag.* **2020**, *8*, 273–284. [CrossRef]
31. Baah, C.; Agyeman, D.O.; Acquah, I.S.; Agyabeng-Mensah, Y.; Afum, E.; Issau, K.; Ofori, D.; Faibil, D. Effect of information sharing in supply chains: Understanding the roles of supply chain visibility, agility, collaboration on supply chain performance. *Benchmark. Int. J.* **2022**, *29*, 434–455. [CrossRef]
32. Krasnikov, A.; Jayachandran, S. The relative impact of marketing, research-and-development, and operations capabilities on firm performance. *J. Mark.* **2008**, *72*, 1–11. [CrossRef]
33. Sabry, A. The impact of supply-chain management capabilities on business performance in Egyptian industrial sector. *Int. J. Bus. Manag.* **2015**, *10*, 251. [CrossRef]
34. Ramaswami, S.N.; Srivastava, R.K.; Bhargava, M. Market-based capabilities and financial performance of firms: Insights into marketing's contribution to firm value. *J. Acad. Mark. Sci.* **2009**, *37*, 97–116. [CrossRef]
35. Fang, E.; Zou, S. Antecedents and consequences of marketing dynamic capabilities in international joint ventures. *J. Int. Bus. Stud.* **2009**, *40*, 742–761. [CrossRef]
36. Zhao, X.D.; Xie, J.X. Several basic concepts of modern supply chain management. *Nankai Bus. Rev.* **1999**, *1*, 62–66.
37. Abdullah, M.; Zailani, S.; Iranmanesh, M.; Jayaraman, K. Barriers to green innovation initiatives among manufacturers: The Malaysian case. *Rev. Manag. Sci.* **2016**, *10*, 683–709. [CrossRef]
38. Kong, T.; Feng, T.; Ye, C. Advanced manufacturing technologies and green innovation: The role of internal environmental collaboration. *Sustainability* **2016**, *8*, 1056. [CrossRef]
39. OECD. *The Measurement of Scientific and Technical Activities*, 3rd ed.; OECD Publishing: Paris, France, 2005.
40. Jian, L. Research on the organization innovation: Conditions methods. *China Soft Sci.* **2011**, *S1*, 225–231.
41. Singh, S.K.; Del Giudice, M.; Chierici, R.; Graziano, D. Green innovation and environmental performance: The role of green transformational leadership and green human resource management. *Technol. Forecast. Soc. Change* **2020**, *150*, 119762. [CrossRef]
42. Shen, H.C.; Tao, Q.; Chen, Y.B. Theory and methods of supply chain management. *China Manag. Sci.* **2012**, *1*, 105–128.
43. Yu, H.S.; Long, Y.H. *Coordination and Resilience*; Science Press: Beijing, China, 2012.
44. Hohenstein, N.O.; Feisel, E.; Hartmann, E.; Giunipero, L. Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. *Int. J. Phys. Distrib. Logist. Manag.* **2015**, *45*, 90–117. [CrossRef]
45. Ali, A.; Mahfouz, A.; Arisha, A. Analysing supply chain resilience: Integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Manag. Int. J.* **2017**, *22*, 16–39. [CrossRef]
46. Ponomarov, S.Y.; Holcomb, M.C. Understanding the concept of supply chain resilience. *Int. J. Logist. Manag.* **2009**, *20*, 124–143. [CrossRef]
47. Chowdhury, M.M.H.; Quaddus, M. Supply chain readiness, response and recovery for resilience. *Supply Chain. Manag. Int. J.* **2016**, *21*, 709–731. [CrossRef]
48. Tukamuhabwa, B.R.; Stevenson, M.; Busby, J.; Zorzini, M. Supply chain resilience: Definition, review and theoretical foundations for further study. *Int. J. Prod. Res.* **2015**, *53*, 5592–5623. [CrossRef]
49. Sahebjamnia, N.; Torabi, S.A.; Mansouri, S.A. Building organizational resilience in the face of multiple disruptions. *Int. J. Prod. Econ.* **2018**, *197*, 63–83. [CrossRef]
50. Liu, C.L.; Shang, K.C.; Lirn, T.C.; Lai, K.H.; Lun, Y.V. Supply chain resilience, firm performance, and management policies in the liner shipping industry. *Transp. Res. Part A Policy Pract.* **2018**, *110*, 202–219. [CrossRef]
51. Gunessee, S.; Subramanian, N.; Ning, K. Natural disasters, PC supply chain and corporate performance. *Int. J. Oper. Prod. Manag.* **2018**, *38*, 1796–1814. [CrossRef]
52. Li, X.; Wu, Q.; Holsapple, C.W.; Goldsby, T. An empirical examination of firm financial performance along dimensions of supply chain resilience. *Manag. Res. Rev.* **2017**, *40*, 254–269. [CrossRef]

53. Soni, U.; Jain, V.; Kumar, S. Measuring supply chain resilience using a deterministic modeling approach. *Comput. Ind. Eng.* **2014**, *74*, 11–25. [CrossRef]
54. Gunasekaran, A.; Patel, C.; Tirtiroglu, E. Performance measures and metrics in a supply chain environment. *Int. J. Oper. Prod. Manag.* **2001**, *21*, 71–87. [CrossRef]
55. Simatupang, T.M.; Sridharan, R. A benchmarking scheme for supply chain collaboration. *Benchmarking Int. J.* **2004**, *11*, 9–30. [CrossRef]
56. Chen, Y.S. The driver of green innovation and green image–green core competence. *J. Bus. Ethics* **2008**, *81*, 531–543. [CrossRef]
57. Chen, Y.S.; Lai, S.B.; Wen, C.T. The influence of green innovation performance on corporate advantage in Taiwan. *J. Bus. Ethics* **2006**, *67*, 331–339. [CrossRef]
58. Chiou, T.Y.; Chan, H.K.; Lettice, F.; Chung, S.H. The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transp. Res. Part E Logist. Transp. Rev.* **2011**, *47*, 822–836. [CrossRef]
59. Manuj, I.; Mentzer, J.T. Global supply chain risk management. *J. Bus. Logist.* **2008**, *29*, 133–156. [CrossRef]
60. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* **1989**, *13*, 319–340. [CrossRef]
61. Venkatesh, V.; Zhang, X. Unified theory of acceptance and use of technology: US vs. China. *J. Glob. Inf. Technol. Manag.* **2010**, *13*, 5–27. [CrossRef]
62. Venkatesh, V.; Morris, M.G.; Davis, G.B.; Davis, F.D. User acceptance of information technology: Toward a unified view. *MIS Q.* **2003**, *27*, 425–478. [CrossRef]
63. Pettit, T.J.; Croxton, K.L.; Fiksel, J. Ensuring supply chain resilience: Development and implementation of an assessment tool. *J. Bus. Logist.* **2013**, *34*, 46–76. [CrossRef]
64. Beamon, B.M. Measuring supply chain performance. *Int. J. Oper. Prod. Manag.* **1999**, *19*, 275–292. [CrossRef]
65. Preacher, K.J.; Hayes, A.F. SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behav. Res. Methods Instrum. Comput.* **2004**, *36*, 717–731. [CrossRef] [PubMed]
66. Preacher, K.J.; Hayes, A.F. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behav. Res. Methods* **2008**, *40*, 879–891. [CrossRef] [PubMed]