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# The Impact of Perceived Benefits on Blockchain Adoption in Supply Chain Management

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**Abstract:** Globalization has prompted enterprises worldwide to increasingly seek the optimal supply chain configuration. However, outsourcing, shortened product life cycles, and a reduced supply base severely weaken supply chain risk tolerance. With the emergence of blockchain, enterprises see an opportunity to mitigate supply chain risks. The purpose of our research is to explore supply chain managers' intention to adopt blockchain technology from the perspective of supply chain risk management. Using a survey sample of 203 managers in China and the USA, we explored the impact of four perceived benefits of blockchain technology on supply chain risk resistance by extending the technology acceptance model. The results show that the traceability, transparency, information sharing, and decentralization of blockchain can enhance the perceived usefulness of blockchain in supply chain resilience and responsiveness, and the ability to withstand disruption risks and supply and demand coordination risks encountered in the supply chain, thus promoting the adoption of the technology. In addition, the relationships between supply chain resilience and blockchain technology adoption and between supply chain responsiveness and blockchain technology adoption are more salient for managers with high levels of uncertainty avoidance.

**Keywords:** blockchain; supply chain risk management; supply chain resilience; supply chain responsiveness; uncertainty avoidance; extended technology acceptance model

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## 1. Introduction

The rapid evolution of global trade has exposed enterprises to highly fluctuating global environmental shocks, placing the survival and development of these enterprises under enormous pressure and with increasing risks [1]. For one thing, commodity flows are vulnerable to disruptions due to natural hazards, strikes, terrorism, and political instability. For example, the disruption of the supply chain caused by the COVID-19 pandemic has had a huge ripple effect on economic activities worldwide. Furthermore, the supply chain is at high risk of supply and demand side fluctuations, such as the uncertainty of customer demand, government regulations, and the suspension of cooperation. For example, demand forecasting becomes more difficult as the fluctuation increases, resulting in a further bullwhip effect [2]. Therefore, when facing challenges related to product safety or production ethics, enterprises find it difficult to trace products in time due to the lack of supply chain traceability [3,4].

In the era of digital transformation and Industry 4.0, many disruptive technologies, such as the Internet of Things and Blockchain, provide the potential for enterprises to enhance their supply chain risk resistance [5]. Blockchain, a peer-to-peer distributed database, has been proven particularly useful in promoting supply chain transparency, safeguarding data security, and improving traceability [3]. For example, companies such as

Walmart, Nestlé, and Unilever have partnered with IBM to use blockchain to ensure food safety and improve their responsiveness to product recalls by tracking product provenance [6]. Some IT manufacturers recently applied a blockchain-based patent to protect privacy and data security in online games [7]. Furthermore, blockchain has been widely used to address the issue of traceability and transparency in different industrial sectors, such as pharmaceutical [8], food [9], and vehicles [10], agriculture [11], etc.

Several studies have examined the factors driving blockchain adoption in supply chain management from various theoretical frameworks, including the technology acceptance model (TAM) [12–15], theory of planned behavior (TPB) [13], unified theory of technology acceptance and use (UTAUT) [12,16–18], and technology–organization–environment theory (TOE) [19–21]. However, while these models propose different benefits of blockchain technology for supply chain management, they fail to describe the relationship between individuals' understanding of the technology and supply chain risk management. The existing literature on the implementation of blockchain technology for risk management to prevent supply chain risks is insufficient, as demonstrated by the limited number of studies [22]. To address this gap, Ivanov, Dolgui and Sokolov [22] provided a comprehensive overview of the potential implications of digital technology and Industry 4.0 on supply chain risk management and highlights the need for further research in this area. Additionally, Chowdhury, et al. [23] proposed a TAM model and finds that the adoption of blockchain technology is positively related to the level of perceived risk resilience in supply chain management. Moreover, Karamchandani, Srivastava and Srivastava [15] identified and tested perceived usefulness of blockchain technology in supply uncertainty as a mechanism mediating the relationship between perceived benefits of blockchain and blockchain adoption. However, it should be noted that Chowdhury, Rodriguez-Espindola, Dey and Budhwar [23] solely considered risk resilience and Karamchandani, Srivastava and Srivastava [15] only focused on supply uncertainty, the multifaceted nature of supply chain risks requires a more comprehensive approach, as highlighted by Ivanov, Dolgui and Sokolov [22]. Therefore, this study aims to provide answers to the following three research questions.

RQ1: What are the perceived benefits of blockchain technology?

RQ2: What is the relationship between perceived benefits and blockchain adoption from the perspective of supply chain risk management?

RQ3: What is the boundary condition of the relationship between perceived benefits and blockchain adoption in supply chain risk management?

Our research aims to explore supply chain managers' intention to adopt blockchain technology from the perspective of supply chain risk management (SCRM). Thus, this study employs an extended TAM framework and structural equation model (SEM), and makes three contributions:

- We clearly demonstrate the features of blockchain in supply chain management and summarize four benefits of blockchain, which are traceability, transparency, information sharing, and decentralization.
- We extend the perceived usefulness of the TAM to the field of SCRM and study the impacts of the four benefits of blockchain on the intention to adopt blockchain through two types of supply chain risk resistance capabilities, which are supply chain resilience and responsiveness.
- We examined the moderating role of uncertainty avoidance cultural values. By elevating cultural differences at the level of uncertainty avoidance cultural values, this study complements the literature on technological acceptance and uncertainty avoidance cultural values.

The remainder of this paper is organized as follows. Section 2 comprises a literature review to understand the current research status of blockchain technology adoption and a summary of blockchain's actual role in the supply chain. Section 3 proposes our research model based on the extended TAM according to the four perceived benefits of blockchain, as summarized in the literature. Section 4 outlines the steps of our survey. The data analysis and results are reported in Section 5 and conclusions are drawn in Section 6. Finally, the study's theoretical contributions, managerial implications, and research limitations, as well as possible future research directions, are presented in Section 7.

## 2. Literature Review and Theoretical Foundation

Supply chain risk management plays a vital role in all organizations, and the application of new technologies in supply chain risk management has attracted widespread attention. In order to understand the willingness of enterprises to adopt blockchain in the supply chain, the literature on supply chain risk management, blockchain, and blockchain technology adoption is reviewed in turn.

### *2.1. Supply Chain Risk Management and Supply Chain Capability*

Effective SCRM is a primary strategic consideration in global supply chains, leading to extensive research on identifying, preventing, detecting, reducing, and responding to supply chain risks [24]. Categorizing supply chain risks is important because it helps practitioners distinguish between risk sources [25]. Based on previous views in SCRM, supply chain risks can be separated into two categories: supply-demand coordination risks and disruption risks [26–28]. Supply-demand coordination risks are caused by changes in customer demand. For example, the demand for personal protective equipment, such as masks and protective suits, soared at the beginning of the COVID-19 outbreak, while raw materials and finished products for these items were in short supply [29]. Disruption risks are caused by factors such as operational risk, natural disasters, terrorism, emergency safety and health incidents, and partner bankruptcy. For example, to control the pandemic's spread, countries implemented lockdowns, severely damaging import and export trade, thereby causing supply chain disruptions. To resist such risks, companies urgently need to develop more cost-effective, robust, and dynamic supply chain capabilities [30]. There are two types of supply-chain-risk-resistant capabilities, supply chain resilience and supply chain responsiveness, that can help alleviate the abovementioned two types of supply chain risks, respectively.

Supply chain resilience refers to a supply chain's ability to prepare for unexpected events and respond to and recover from disruptions, by maintaining operational continuity and controlling structure and function at the required level of connectivity [31,32]. Supply chain resilience enables supply chain members to endure difficulties and adversities and gain an advantage in the chaos through better positioning than their competitors. Therefore, supply chain resilience can help enterprises to quickly revert to normal levels when enterprises encounter supply chain disruptions [33].

Supply chain responsiveness refers to an enterprise's ability to effectively adjust to demand and supply changes by modifying production quantities, delivery, and product portfolios over time [34]. Supply chain responsiveness reflects the flexibility of operations and can help companies respond to market dynamics effectively. Therefore, supply chain responsiveness can help enterprises effectively coordinate the tension between supply and demand in response to risks caused by customer demand uncertainty, information asymmetry, and market competition.

### *2.2. Application of Blockchain in the Supply Chain and Its Benefits*

Blockchain is mainly used to record transaction data or other information, which is encrypted with hash functions and distributed across nodes. When an agent node in the blockchain wants to add a new transaction to the chain, it needs to be broadcast to the entire network for verification. Only if a majority of nodes agree that the transaction has passed a consensus mechanism can the information be encrypted into a new time-stamped block and copied to each node [4].

Early studies on blockchain have primarily focused on technical research about Bitcoin and other application analyses. However, with the evolution of blockchain technology and its potential to revolutionize operations and supply chain management (OSCM), it has gained considerable attention in recent years. A number of studies have explored how blockchain works for OSCM from various perspectives. For instance, in the field of operation management, Babich and Hilary [35] highlighted five key strengths of blockchain technology, such as visibility, aggregation, validation, automation, and resiliency. In addition, scholars have identified others critical features, including traceability, transparency, permanent record, reliable data, distributed ledgers, cryptocurrency, smart contract, and low information sharing/disclosure cost [36]. In the realm of supply chain management, Centobelli, et al. [37] explored the potential of blockchain technology for bridging trust, traceability, and transparency in circular supply chains, while others have examined immutability, transparency, disintermediation, irreversibility, automation, efficiency, and security [38–40]. Appendix A provides a summary of blockchain's benefits in OSCM. Based on this literature and blockchain's operational principles, we argue that blockchain technology can provide four benefits to supply chain management, namely, traceability, trusted information sharing, transparency, and decentralization.

*Traceability:* Blockchain technology facilitates traceability for supply chain information by collecting, recording, and storing distributed time-stamped data during production, transportation, and sales [11]. This information records the provenance of each product, thus effectively combating the counterfeiting of pharmaceuticals, diamonds, and luxury goods [41]. Traceability has enabled the large-scale adoption of blockchain in agriculture [11], food [9], and pharmaceuticals [8], such as IBM's TradeLens and Food Trust projects.

*Trusted information sharing:* Typically, data on blockchain are encrypted through hash functions, which is similar to interlocking, causing data on each piece to contain arrays representing the previous block [42]. Information on the blockchain is tamper-proof because data modification requires the rearrangement of data in the entire chain and decentralized verification through a consensus mechanism [43]. Therefore, this valuable information can be turned into reliable transaction vouchers for supply chain financial enterprises, such as Ant Financial Services Group, Tencent Financial Technology, One Connect, and Jingdong Finance [29].

*Transparency:* The data in the blockchain are distributed to each network member, and the addition of any data into the chains needs to be audited and agreed upon by most nodes in the blockchain. Thus, the data on the blockchain are visible to all supply chain participants. This transparency has been applied in practice, such as the blockchain collaboration platform created by IBM and Maersk [22].

*Decentralization:* The metadata are distributed across the network in the blockchain. Therefore, compared with centralized ledgers, a key advantage of blockchain is Byzantine fault tolerance; that is, the breakdown of a single component/node in the blockchain will not paralyze the entire system [35]. This decentralized nature has prompted communication companies, financial institutions, and government departments to actively build information systems based on blockchain [44].

### *2.3. Blockchain Adoption and an Extended TAM*

Scholars have conducted extensive investigations into the factors influencing blockchain adoption and the obstacles or challenges that hinder it through expert interviews and case studies. For example, Janssen, et al. [45] proposed a theoretical framework that integrates institutional, market, and technical factors for analyzing blockchain adoption, while others have investigated the challenges and implications of blockchain and proposed a conceptual framework based on interviews [46]. However, empirical research has obtained much more attention. For example, facilitating conditions, trust, social influence, and effort expectancy have been found to be the main factors affecting blockchain adoption based on a UTAUT model [17]. Moreover, a TOE framework which studied the technological, environmental, and organizational factors influencing blockchain adoption has been proposed [20]. Others have developed integrated models of blockchain technology adoption, such the integration of TAM, TRI, and TPB [13] and the integration of TAM and UTAUT [12]. Appendix B provides a more detailed review of these models. However, these theories do not adequately predict adoption intentions in supply chain from the perspective of SCRM. UTAUT only considers the exogenous conditions affecting technology acceptance from the level of individual motivation, such as performance expectancy and facilitating conditions [16]. TOE proposes the factors affecting the adoption of organizational technology from three broad perspectives: technology, organization, and environment [19,20], while ignoring the mechanism of technological factors on adoption. Furthermore, TPB is used to explain general human behavior based on three factors: attitudes, subjective norms, and perceived behavioral control [13].

Moreover, TAM has received great attention in operations management and corporate strategy. However, two key variables, perceived usefulness and perceived ease-of-use, are related to how well individuals cognize the technology, which is not well described in TAM. The extended TAM model developed by Venkatesh and Davis [47] outlined the relationship between cognitive instruments, such as the output quality, and perceived usefulness. Moreover, perceived usefulness could also be extended to various dimensions [15]. Therefore, based on such existing studies on SCRM and blockchain adoption (Appendix B), this study expands perceived usefulness to two dimensions to understand the impact of four blockchain benefits on technology adoption from the perspective of SCRM by using an extended TAM model.

## 3. Research Model and Hypotheses Development

Based on the theoretical framework of the extended TAM model, this paper constructs the conceptual model of our study. As shown in Figure 1, the model of this study aims to explore the relationship between the perceived benefits of blockchain and the intention to adopt. By doing so, this study reveals the relationship between the perceived benefits of blockchain and the perceived usefulness (PU) of blockchain (BC) in supply chain resilience and responsiveness, and further examines the role of cultural values on the relationship between perceived benefits on blockchain adoption is supply chain management (SCM).

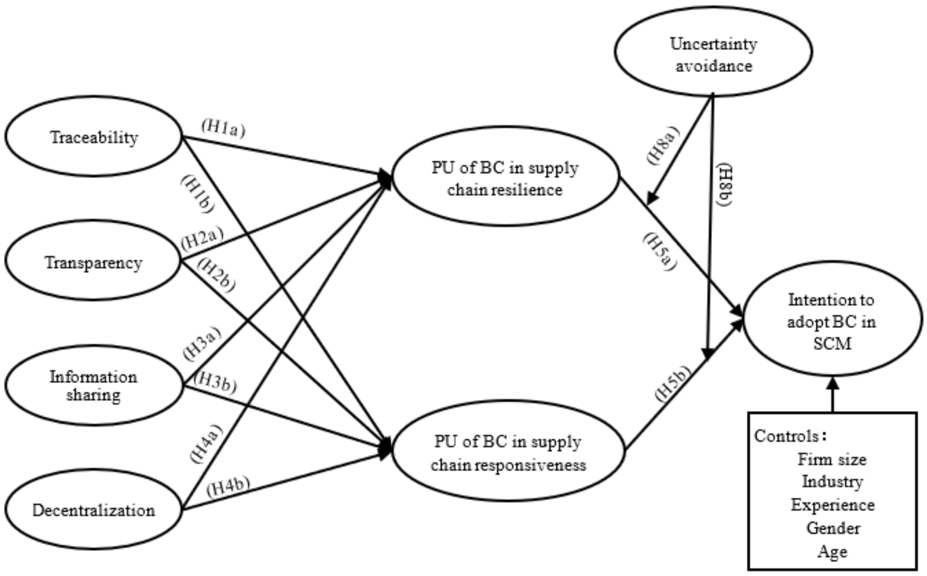



**Figure 1.** Conceptual model.

### 3.1. Traceability and Perceived Usefulness

Traceability refers to the ability of companies to use blockchain to trace the upstream source of raw materials [48]. Generally, the source information includes the name and address of the upstream supplier and details related to manufacturing, such as whether the production process complies with laws and ethics [3]. The traceability of blockchain makes it easy to track and monitor information from both upstream and downstream in the supply chain [18]. At each transaction node, the blockchain automatically labels the product using a digital marker, such as a timestamp [49]. The digital marker is unique to this blockchain, allowing it to record and transmit data in a single-truth version, which can be utilized to verify the product's origin.

The traceability of blockchain helps to achieve supply chain resilience. The transactions of all partners in the supply chain can be verified through the consensus mechanism and monitored by all parties in the supply chain [3]. Monitoring and tracking can reduce information asymmetry, thus making the entire supply chain more robust in the face of disruptions and improving supply chain resilience. In addition, tracking can increase supply chain agility, which is considered a significant source of supply chain resilience, especially involving disruptions regarding raw materials and components [26]. Babich and Hilary point out that tracing product movement helps to identify risks and predict their consequences, thereby mitigating the impact of disruptions [35].

The traceability of blockchain enables supply chain responsiveness. Traceability cannot be realized by only one company but by all enterprises participating in the supply chain [50]. Integrating efforts throughout the supply chain achieves an effective response to changing customer needs. Blockchain can aggregate the data from all the enterprises in the supply chain into a synthesis, especially production details [51]. Information integration can improve the accuracy and trustworthiness of information, which is conducive to evaluating supply chain risk and achieving supply chain responsiveness. Traceability also reduces opportunism by turning the entire supply chain into a trust chain [50].

Accordingly, we propose the following hypothesis:

**H1:** *Traceability positively impacts the perceived usefulness of blockchain in (a) supply chain resilience and (b) supply chain responsiveness.*

### 3.2. Transparency and Perceived Usefulness

Blockchain is a critical technology for improving supply chain transparency. Transparency refers to the openness and availability of information on the blockchain [52]. Increased transparency can reduce fraud in the supply chain because fraud can be easily detected.

Compared to the conventional supply chain, which lacks open and trusted information sources, blockchain can enhance the transparency of supply chain networks [12]. When supply chain networks become clear and supply chain visibility is enhanced, more effective partnership governance can be achieved and supply risks are reduced [53]. Tian et al. argue that information transparency, especially logistics information, can gain the trust of stakeholders, such as through customer loyalty and bank investments [52]. When customers are loyal to the enterprise, companies are more likely to receive actual demand information. Maintaining transparency can also help companies meet the regulatory needs of stakeholders [48], such as governments and NGOs. Therefore, blockchain transparency increases supply chain responsiveness by reducing supply risks and helping receive stakeholder assistance.

The transparency and visibility of information provided by blockchain systems can help businesses make decisions on control and adaptation in an uncertain environment [18]. Sodhi and Tang believe that visibility can help enterprises avoid, mitigate, and respond to supply chain disruptions [48]. In addition, more transparent and reliable supply chain processes can improve trust-related issues in transactions, making supply chains efficient. An efficient, reliable, and transparent supply chain can help companies identify available supply chain resources and reduce inventory costs during disruptions, thus helping enterprises recover as quickly as possible [22].

Accordingly, we propose the following hypothesis:

**H2:** *Transparency positively impacts the perceived usefulness of blockchain in (a) supply chain resilience and (b) supply chain responsiveness.*

### 3.3. Information Sharing and Perceived Usefulness

Transactions on the blockchain cannot be deleted or tampered with and can only be interpreted by adding new information by consensus [54]. Invariable information makes transactions on the blockchain auditable, which reduces fraud and product adulteration and helps enterprises sustain continuous operations [29]. Reliable blockchain technology can help improve operational efficiency by simplifying supply chain processes, reducing paperwork, and even replacing paper documents that are easily altered and lost [49]. In addition, the consensus mechanism significantly advances the fault tolerance of the data, thereby increasing the security of the information system in combination with cryptography [55]. The immutable, credible, and secure information shared by blockchain improves the operational efficiency, reduces potential conflicts over specific transactions, and increases the timeliness of information sharing, thereby enhancing the supply chain responsiveness[18].

Supply chain participants encrypt information about trade secrets, which promotes frequent communication between trading partners [49]. Effective communication facilitates coordination, cooperation, and learning among partners. Accurate information and collaboration increase the supply chain's recovery capacity to enhance the supply chain resilience. In addition, supply chain managers can obtain abundant data via the blockchain for more extensive descriptive, predictive, and illustrative analysis, enhancing the company's analytical capabilities and effectively responding to disruptions [53].

Accordingly, we propose the following hypothesis:

**H3:** *Information sharing positively impacts the perceived usefulness of blockchain in (a) supply chain resilience and (b) supply chain responsiveness*.

### 3.4. Decentralization and Perceived Usefulness

Blockchain transaction data are stored in a ledger composed of multiple members. Compared with centralized databases, decentralized databases are less likely to be easily damaged, tampered with, or lead to information asymmetry. Decentralization allows the verification of transactions without intermediaries, reducing the complexity and uncertainty of the transaction process [29,56]. Blockchain technology provides automated fair trade, reduces transaction costs, and improves rapid response [6]. Moreover, the consensus mechanism eliminates reliance on the central authority [18,57]. The decentralized structure causes real-time data recording and updating, thereby improving the level of supply chain collaboration and then supply chain responsiveness.

The distributed nature of blockchain networks can help companies mitigate the impact of centralized attacks or accidents [49]. In other words, the damage to the decentralized database caused by the disruption of a node is significantly reduced, thus increasing the resilience of the supply chain to a single-point attack. A decentralized database can enhance trust among supply chain partners and facilitate the development of a multivendor network base [11]. Securing flexible and redundant suppliers is beneficial for establishing a resilient supply chain. Hence, blockchain enables enterprises to make timely responses and decisions in handling periodic changes and customer demand emergencies.

Accordingly, we propose the following hypothesis:

**H4:** *Decentralization positively impacts the perceived usefulness of blockchain in (a) supply chain resilience and (b) supply chain responsiveness.*

### *3.5. Perceived Usefulness and Intention to Use*

In TAM, perceived usefulness refers to the extent to which individuals believe that the technology can improve job performance. Applied at the organizational level, perceived usefulness refers to the degree to which the organization believes that adopting a certain technology can increase productivity [58]. The motivation of enterprises to adopt a new technology is related to the perceived advantages of such technology in business operations. Perceived usefulness has proven to be a dominant factor affecting the intention to use blockchain [15].

In this study, perceived usefulness is defined as the extent to which organizational managers believe that blockchain adoption can improve supply chain resilience and responsiveness. Specifically, the perceived usefulness of blockchain in supply chain resilience refers to the extent to which managers believe that adopting blockchain can help companies reduce the possibility of disruptions and quickly recover from them [39], and thus can have a positive impact on the market and financial performance by dealing with various types and levels of disruption. The perceived usefulness of blockchain in supply chain responsiveness refers to the extent to which managers believe that adopting blockchain can prompt businesses to respond quickly to customer needs and enviromental challenges [34], which is considered to be a dimension of supply chain capability, reflecting the efficiency and effectiveness of an enterprise's actions to deal with market volatility, and promoting the improvement of financial, operational, and competitive performance [59]. Based on this, we believe that managers' intention to adopt blockchain will increase when managers realize that blockchain can significantly improve supply chain resilience and responsiveness.

Accordingly, we propose the following hypothesis:

**H5:** *The perceived usefulness of blockchain in (a) supply chain resilience and (b) supply chain responsiveness positively impacts the intention to use blockchain.*

Blockchain has been proven to have a serious impact on supply chain management, especially for SCRM [35]. By establishing a collaboration platform through blockchain, companies can share data about demand forecasting and inventory levels to enhance risk management processes [39]. Moreover, blockchain can reduce network security risks, decrease the volatility of customer demand, and weaken the impact of ripple effects [22].

In essence, credible collaboration, secure communication channels, trust, information sharing, and the decentralized structures of the blockchain can enhance supply chain resilience [39]. Blockchain is further believed to make supply chains sensitive to market changes or trends. Xiong, et al. [60] prove that using blockchain in the supply chain can mitigate the negative impact of COVID-19 on enterprises' stock performance. Yoon, et al. [61] demonstrate through simulation and numerical analysis that blockchain helps businesses respond to demand fluctuations in international trade. Blockchain can help the supply chain implement automated transactions and increase visibility on both the supply and demand sides, which are verified as drivers of responsiveness.

Accordingly, we propose the following hypotheses:

**H6:** *The perceived usefulness of blockchain in supply chain resilience mediates the relationship between (a) traceability, (b) transparency, (c) information sharing, (d) decentralization, and the intention to use blockchain.*

**H7:** *The perceived usefulness of blockchain in supply chain responsiveness mediates the relationship between (a) traceability, (b) transparency, (c) information sharing, (d) decentralization, and the intention to use blockchain.*

### *3.6. The Moderating Role of Uncertainty Avoidance*

Cultures differ regarding risk cognition and processing, instilling people with different degrees of the acceptance of risk. As a common cultural dimension, uncertainty avoidance, defined as the degree to which a cultural group feels uncomfortable with uncertainty and ambiguity, is closely related to trust and high uncertainty avoidance refers to an aversion to risk. Adopting a new technology presents many risks, such as data security challenges, privacy leaks, technology immaturity, and hidden costs [4,43,46]. Lee, et al. [62] argue that people with a high uncertainty avoidance culture values will hesitate to make decisions until the risk of technology acceptance disappears. However, from the perspective of SCRM, blockchain technology can help enterprises avoid and mitigate the impact of supply chain risks by enhancing supply chain resilience and responsiveness. Hofstede [63] believes that people who have a high level of uncertainty avoidance also become adventurous when risks are known. The risks of technology acceptance are assessable compared to unknown and unpredictable disruptions. Therefore, people who pursue certainty will more actively use blockchain technology.

Accordingly, we propose the following hypothesis:

**H8:** *Compared to people with low uncertainty avoidance, people with high uncertainty avoidance will show a stronger relationship between the perceived usefulness of blockchain in (a) supply chain resilience, (b) supply chain responsiveness, and the intention to use it.*

## 4. Research Methodology

### *4.1. Measurements*

In addition to decentralization, the measurement items of the variables involved in this study are adapted from mature scales in previous authoritative literature, as shown in Appendix C. All items are measured by the 7-point Likert scale (where 1 indicates *strongly disagree* and 7 indicates *strongly agree*).

*Traceability (Trace).* Traceability primarily measures the role of blockchain in tracing products across the supply chain. The items are adapted from Cousins, Lawson, Petersen and Fugate [50].

*Transparency (Trans).* Transparency mainly measures the role of blockchain in helping supply chain processes and information to be transparent. The items are adapted from Fosso Wamba, Queiroz and Trinchera [12].

*Information Sharing (IS).* Information sharing mainly measures the role of blockchain in promoting the exchange of information among supply chain participants. The items are adapted from Cai, et al. [64].

*Decentralization (Decent).* According to the descriptive statements of decentralization in the literature and blockchain's working principle [65], we developed decentralization measurements with items mainly related to topics such as "power distribution", "node participation", and "consensus mechanism". Subsequently, to establish the content validity of decentralization, two colleagues independently evaluated the relationship between the concept of decentralization and the developed items. The researchers then discussed the measurement of decentralization until an agreement was reached on their appropriateness. Ultimately, the decentralization measurement contains five items.

*Perceived usefulness (PU).* In our study, the two dimensions of perceived usefulness, *PU of Blockchain (BC) in Supply Chain Resilience (SCR)* and *PU of BC in Supply Chain Responsiveness (Resp)*, refer to the degree to which the use of blockchain is believed to improve supply chain resilience and responsiveness, respectively. Therefore, based on the previous measurements of supply chain resilience and responsiveness [33,34], we added background information on "After using blockchain, your company's supply chain will…" for each question.

*Uncertainty Avoidance (UA).* The scales of uncertainty avoidance are derived from Srite and Karahanna [66] and have been examined by many scholars as individual difference variables to test their impacts on technology adoption [67].

Moreover, we include several covariates to account for the possible influences of exogenous variance on the dependent variable. Consistent with previous research, we introduce gender, age, education, field of work, years of work experience, and position, to control participant heterogeneity [68,69]. In addition, an individual's knowledge and user experience of a technology will affect the judgment of usability. Based on previous literature, this study regards experience as a covariate for controlling individual differences. As blockchain technology involves acceptance behavior at the organizational level, we also control for company-level variables, including company size and industry type. Differences in financial scale and business complexity caused by company size may influence the adoption of supply chain management systems, and the different impacts of blockchain technology on different industries will have a similar effect.

As all the measurements cited were in English and the Chinese samples were included in this study, back-translation was used to solve such problems [64]. One group of bilingual researchers translated the English items into Chinese, while the other group translated the Chinese version into English. Later, two professors of Management Information Systems checked and corrected the accuracy and professionalism of the statements. The Chinese version of the questionnaire was first previewed by a supply chain manager and a senior executive of a blockchain application company to ensure face validity and content validity. Finally, we revised some of the wording based on feedback.

### 4.2. Data and Sample

From a multinational blockchain service provider, we obtained a list of 318 companies that have used blockchain, which were either clients or partners of clients. According to the list, the questionnaire was published online by a professional sample collection agency, collecting data from both the USA and China. The questionnaires were disseminated to supply chain professionals who had experience with blockchain projects in these firms. The online questionnaire comprised three parts. First, screening questions such as "Have you used blockchain for supply chain related work?" were set to ensure that the subjects had a sufficient understanding of supply chain management and blockchain. All final selected samples chose "yes". The second part of the questionnaire included a video of the introduction to blockchain, with easy-to-understand blockchain principles and case explanations (video available at https://www.bilibili.com/video/BV1u64y147by?spm_id_from=333.999.0.0, accessed on 13 April 2023), and the participants needed to carefully watch this video to answer the formal questionnaire. Finally, the third part of the questionnaire included some demographic characteristics of the participants and control variables at the company level.

Out of 318 questionnaires, a total of 207 questionnaires were collected in this survey, of which 203 were valid, with an effective response rate of 63.84%. The valid questionnaires contained 106 samples from the USA and 97 samples from China. The gender distribution of the samples in the two countries was similar, with the male-to-female ratio approaching 1:1. About half the respondents belonged to the age range of 31–40 years. The vast majority of them had been working in the dolphin choir for more than 3 years and were distributed across different fields of supply chain management. Our study included junior and middle managers since their opinions have a considerable impact on the adoption of new technologies in an organization. Regarding education, all respondents held at least a bachelor's degree. Appendix D further details the respondents' characteristics.

### 4.3. Non-Response and Common Method Bias

Although we sent out the invitation to the managers at the same time, the questionnaires were filled out from 9 July 2021, to 3 August 2021, with a time span of nearly one month. Hence, we verified the non-response bias by comparing whether there were significant differences in responses between early and late respondents in China and the USA. Six items in the questionnaire were randomly selected, and an independent sample t-test was performed between the initial and last 20 responses in each country. The t-values of the difference between the early and late responses are much higher than the 0.05 level (China, $p_{min}$ = 0.163; USA, $p_{min}$ = 0.062). Therefore, we concluded that there was no evidence of a non-response bias.

The 1uestionnaire-based survey may have the problem of common method bias (CMB), which can overstate estimates of coefficients between variables [70,71]. To avoid the influence of CMB, we provided a cover-up story with clear instructions at the beginning of the questionnaire and guaranteed the anonymity of the participants. Moreover, we performed Harman's one-factor test before further analysis and we found that (1) more than one factor was identified and (2) the maximum explanatory variance for a single factor was 39.618%. Therefore, CMB is not of concern in this study. Moreover, we also added a new factor (technology uncertainty) to the confirmatory factor analysis (CFA) and took the three measurements of this construct and the items of all the constructs in the study model as indicators. By comparing CFA models with and without direct measurement error factors, we found that the factor loadings and model fitting significantly worsened ($\Delta\chi^2$ = 169.844, $\Delta$df = 52), which further demonstrate that CMB is of secondary concern in this study.

## 5. Results

The structural equation model (SEM) is a statistical technique that can simultaneously analyze relationships among constructs and is widely used in behavioral sciences [23]. Thus, we employed an SEM to test the hypotheses. Mplus 7.4 was adopted to simultaneously estimate the measurement and structural models. Previous studies recommend that the required valid minimum sample size for maximum likelihood estimation should be at least between 100 and 150. This study, with 203 valid responses, met the pre-conditions of the minimum required responses.

### *5.1. Validation of the Measurement Model*

#### 5.1.1. Exploratory Factor Analysis (EFA)

As the scales are adapted from previous literature, an EFA model was first used to test the unidimensionality of the constructs. We assessed the overall fitness of the measurement model with the following six fitting indices: $\chi^2$, the ratio of $\chi^2$ to the degree of freedom ($\chi^2$/df), comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). The EFA procedure generated an acceptable model fit with $\chi^2$= 128.950, df = 112, $\chi^2$/df = 1.151, CFI = 0.993, TLI = 0.982, RMSEA = 0.027, and SRMR = 0.017, which are acceptable. Finally, eight factors were extracted from all indicators: traceability (Trace), transparency (Trans), information sharing (IS), decentralization (Decent), PU of BC in supply chain resilience (SCR), PU of BC in supply chain responsiveness (Resp), uncertainty avoidance (UA), and intention to use (IU) (Table 1).

**Table 1.** Loading and cross-loading values.

| Construct | Trace | Trans | IS | Decent | SCR | Resp | UA | IU |
|---|---|---|---|---|---|---|---|---|
| Trace2 | 0.673 | | | | | | | |
| Trace3 | 0.689 | | | | | | | |
| Trace4 | 0.607 | | | | | | | |
| Trans1 | | 0.673 | | | | | | |
| Trans2 | | 0.649 | | | | | | |
| Trans4 | | 0.671 | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IS1 | | | 0.610 | | | | | |
| IS2 | | | 0.612 | | | | | |
| IS5 | | | 0.780 | | | | | |
| Decent2 | | | | 0.685 | | | | |
| Decent3 | | | | 0.681 | | | | |
| Decent4 | | | | 0.706 | | | | |
| SCR1 | | | | | 0.739 | | | |
| SCR2 | | | | | 0.664 | | | |
| SCR4 | | | | | 0.657 | | | |
| Resp2 | | | | | | 0.675 | | |
| Resp3 | | | | | | 0.606 | | |
| Resp4 | | | | | | 0.656 | | |
| UA1 | | | | | | | 0.706 | |
| UA3 | | | | | | | 0.766 | |
| UA5 | | | | | | | 0.610 | |
| IU1 | | | | | | | | 0.697 |
| IU2 | | | | | | | | 0.611 |
| IU3 | | | | | | | | 0.651 |

Note: values less than 0.4 are hidden.

### 5.1.2. Confirmatory Factor Analysis (CFA)

We then used CFA with maximum likelihood estimation to verify the convergent and discriminative validity of the measures. All the fitting indices of CFA met the recommended values ($\chi^2$= 256.580, df = 124, $\chi^2$/df = 1.145, CFI = 0.986, TLI = 0.983, RMSEA = 0.027, and SRMR = 0.037). Table 2 shows the values of the standardized factor loadings, composite reliability (CR), and average variance extracted (AVE). All factor loadings exceeded 0.60, ranging from 0.698 to 0.841; the CRs were greater than 0.70, ranging from 0.787 to 0.829; and the AVE values were all higher than 0.50, which affirms the convergent validity of all constructs.

**Table 2.** Factor loadings and reliability results.

| Variance | Items | Factor Loadings | Cronbach's Alpha | CR | AVE |
|---|---|---|---|---|---|
| Traceability | Trace2 | 0.774 | 0.806 | 0.806 | 0.580 |
| | Trace3 | 0.774 | | | |
| | Trace4 | 0.737 | | | |
| Transparency | Trans1 | 0.774 | 0.806 | 0.808 | 0.584 |
| | Trans2 | 0.728 | | | |
| | Trans4 | 0.789 | | | |
| Information Sharing | IS1 | 0.765 | 0.829 | 0.829 | 0.617 |
| | IS2 | 0.832 | | | |
| | IS5 | 0.757 | | | |
| Decentration | Decen2 | 0.700 | 0.791 | 0.792 | 0.562 |
| | Decen3 | 0.698 | | | |
| | Decen4 | 0.841 | | | |
| PU of BC in Supply Chain Resilience | SCR1 | 0.769 | 0.827 | 0.829 | 0.618 |
| | SCR2 | 0.821 | | | |
| | SCR4 | 0.768 | | | |
| PU of BC in Supply Chain Responsiveness | respon2 | 0.767 | 0.811 | 0.812 | 0.591 |
| | respon3 | 0.716 | | | |
| | respon4 | 0.819 | | | |

| | | | | | |
|---|---|---|---|---|---|
| | UA1 | 0.754 | | | |
| Uncertainty Avoidance | UA3 | 0.770 | 0.785 | 0.787 | 0.552 |
| | UA5 | 0.703 | | | |
| | IU1 | 0.814 | | | |
| Intention to Use Blockchain | IU2 | 0.762 | 0.822 | 0.823 | 0.608 |
| | IU3 | 0.762 | | | |

Note: CR = composite reliability; AVE = average variance extracted.

The squared roots of the AVEs and correlation coefficients between the paired constructs were used to confirm discriminant validity. Table 3 presents the square roots of the AVE values on the diagonal in bold. The results showed that all the square roots of the AVE values were greater than the correlations between the constructs. Therefore, discriminant validity was ensured in the present study.

**Table 3.** Inter-construct correlations and reliability measures.

| Construct | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Trace | **0.762** | | | | | | | |
| Trans | 0.378 | **0.764** | | | | | | |
| IS | 0.342 | 0.451 | **0.785** | | | | | |
| Decent | 0.295 | 0.362 | 0.387 | **0.750** | | | | |
| SCR | 0.491 | 0.545 | 0.490 | 0.421 | **0.786** | | | |
| Resp | 0.346 | 0.401 | 0.454 | 0.402 | 0.405 | **0.769** | | |
| UA | 0.251 | 0.232 | 0.237 | 0.172 | 0.346 | 0.397 | **0.743** | |
| IU | 0.456 | 0.476 | 0.554 | 0.453 | 0.535 | 0.501 | 0.327 | **0.780** |

Note: Square roots of average variance extracted are shown on the diagonal.

### 5.2. Main Effects

We conducted a multicollinearity test before checking the validity of the structural model. The results showed that the variance inflation factors (VIFs) were all less than 3 ($VIF_{max}$ = 2.494). Therefore, multicollinearity was not a serious problem in our study. The base model containing only the control variables and dependent variables was first estimated. We then included the focal predictor variables and the mediator variables (main effect model), which served as the basis for testing our hypotheses ($\chi^2$= 198.923, df = 173, $\chi^2$/df = 1.150, CFI = 0.987, TLI = 0.985, RMSEA = 0.027, and SRMR = 0.038).

Figure 2 shows the hypotheses testing results of the main effects. The results provided evidence of the expected positive effects of traceability ($\beta$ = 0.229, $p$ < 0.01; H1a), transparency ($\beta$ = 0.321, $p$ < 0.001; H2a), information sharing ($\beta$ = 0.262, $p$ < 0.01; H3a), and decentralization ($\beta$ = 0.182, $p$ < 0.05; H4a) on SCR, and significant effects of traceability ($\beta$ = 0.213, $p$ < 0.05; H1b), transparency ($\beta$ = 0.221, $p$ < 0.05; H2b), information sharing ($\beta$ = 0.261, $p$ < 0.05; H3b), and decentralization ($\beta$ = 0.253, $p$ < 0.01; H4b) on Resp. We also found significant positive impacts of SCR ($\beta$ = 0.522, $p$ < 0.001; H5a) and Resp ($\beta$ = 0.412, $p$ < 0.001; H5b) on the intention to use blockchain. In sum, the empirical results support that the perceived benefits of blockchain positively relate to blockchain adoption.

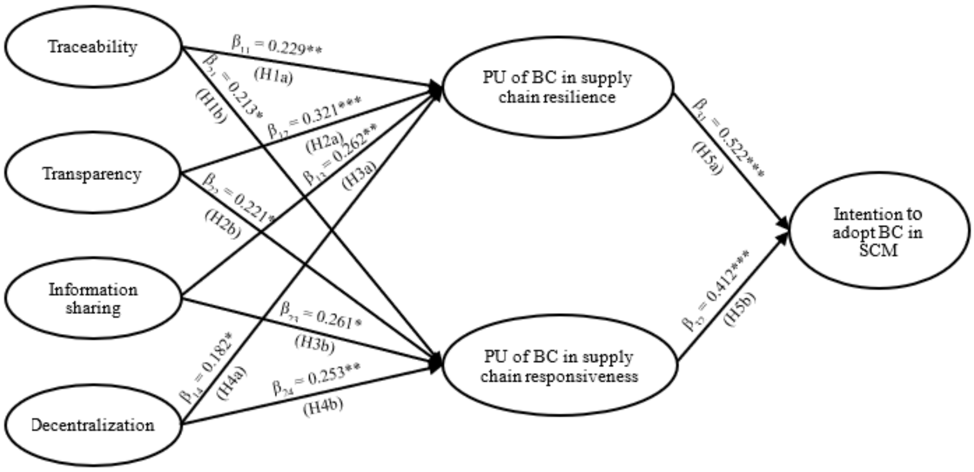



**Figure 2.** Hypothesis test results: main effects. Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

### 5.3. Mediation Effects

We tested the statistical significance of the indirect effects using bias-corrected bootstrapping with 5000 samples and 95% confidence intervals. The structural model had a desired fit with the data, as reflected in the fitness indices: $\chi^2$= 198.923, df = 173, $\chi^2$/df = 1.150, CFI = 0.987, TLI = 0.985, RMSEA = 0.027, and SRMR = 0.038.

The results in Table 4 show that 0 was not contained in all confidence intervals of the indirect effects, indicating that all of the null hypotheses were rejected. It is confirmed that SCR and Resp had significant mediating effects between the four blockchain benefits and intention to use blockchain, supporting H6(a, b, c, d) and H7(a, b, c, d).

**Table 4.** Mediation effects.

| Path | Effect | SE | 95% CI |
|---|---|---|---|
| Traceability→SCR→Intention to use blockchain | 0.120 | 0.070 | [0.028, 0.313] |
| Traceability→Resp→Intention to use blockchain | 0.088 | 0.061 | [0.006, 0.258] |
| Transparency→SCR→Intention to use blockchain | 0.167 | 0.089 | [0.028, 0.370] |
| Transparency→Resp→Intention to use blockchain | 0.091 | 0.065 | [0.001, 0.259] |
| Information Sharing→SCR→Intention to use blockchain | 0.137 | 0.075 | [0.031, 0.339] |
| Information Sharing→Resp→Intention to use blockchain | 0.107 | 0.080 | [0.003, 0.319] |
| Decentration→SCR→Intention to use blockchain | 0.095 | 0.058 | [0.016, 0.256] |
| Decentration→Resp→Intention to use blockchain | 0.104 | 0.067 | [0.014, 0.278] |

Note: bootstrap resample = 5000. SE = standard error; CI = confidence interval. Resp = PU of BC in supply chain responsiveness; SCR = PU of BC in supply chain resilience.

### 5.4. Moderation Effects

To examine the moderating effect of uncertainty avoidance (UA), latent interaction terms between moderating and mediating variables were generated after mean-centering (Figure 3), and then the model was estimated using SEM.

The results verify that UA only significantly positively moderates the effects of Resp ($\gamma$ = 0.147, $p$ = 0.019; H8b) on the intention to use blockchain. However, there is no support for the moderating effect of UA on the corresponding impact of SCR ($\gamma$ = 0.085, $p$ = 0.211; H8a) on the intention to use blockchain. The results made some contributions to the research on uncertainty avoidance in blockchain adoption when considering different risks.

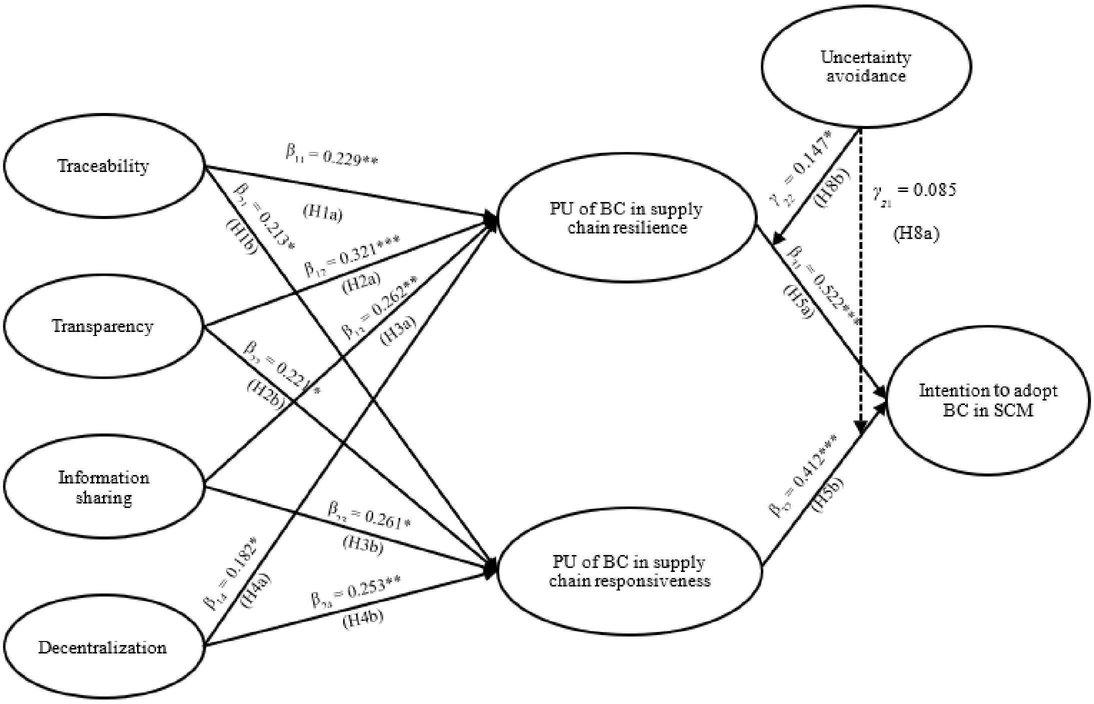



**Figure 3.** Hypothesis test results: moderating effects. Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Dashed paths are not significant at 0.05 level.

To further examine the moderated effect of UA, we analyze the simple slopes (marginal effects) of SCR and that of Resp over three levels of moderating variable, which are one standard deviation below the mean (−1σ), at the mean, and above the mean (+1σ). The first partial derivatives (simple slopes) of the intention to use blockchain (IU) on the mediating variables (SCR, Resp) are represented as follows:

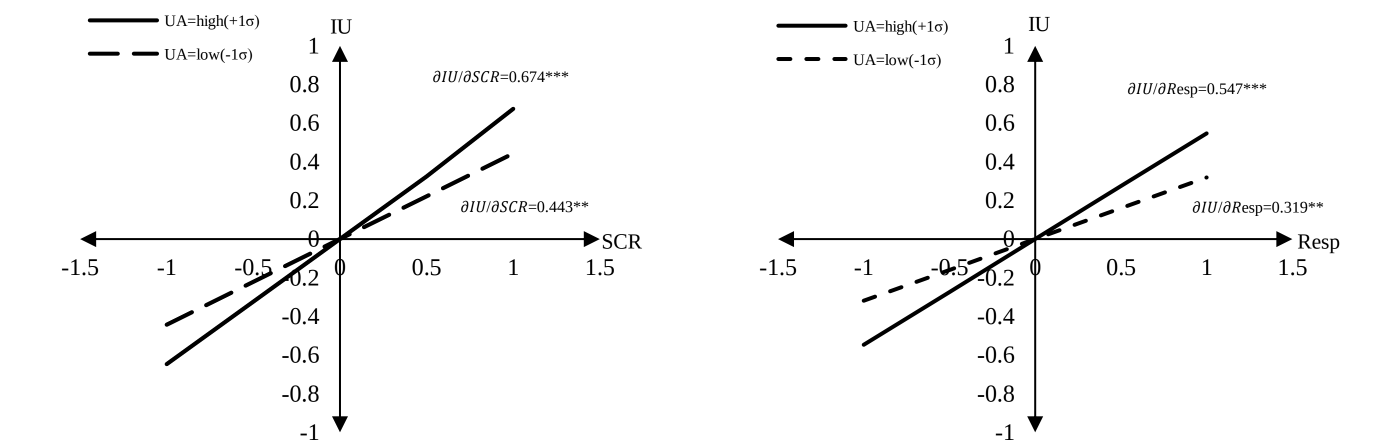
$$\partial IU/\partial \mathrm{SCR} = \beta_{\mathrm{SCR}} + \gamma_{\mathrm{SCR \times UA}} \times \mathrm{UA} \quad (1)$$

$$\partial IU/\partial \mathrm{Resp} = \beta_{\mathrm{Resp}} + \gamma_{\mathrm{Resp \times UA}} \times \mathrm{UA} \quad (2)$$

Moreover, unstandardized coefficients and mean-centered data were used to calculate the simple slope. The results of the slope analyses in Table 5 confirm the moderating analyses.

**Table 5.** Results of simple slope analyses (marginal effects).

| **Dependent Variable: Intention to Use Blockchain (IU)** | | | | |
|---|---|---|---|---|
| | | **The Marginal Effect when the Uncertainty Avoidance (UA) is…** | | |
| | | **…low(−1σ)** | **…mean** | **…high(+1σ)** |
| PU of BC in supply chain resilience (SCR) | $\partial IU/\partial$SCR=0.545+0.118×UA | 0.443 ** | 0.545 *** | 0.647 *** |
| PU of BC in supply chain responsiveness (Resp) | $\partial IU/\partial$Resp=0.433+0.131×UA | 0.319 ** | 0.433 *** | 0.547 *** |
| **Visualization of Simple Slope Results** | | | | |
| Simple Slopes of SCR over UA+1σ and UA−1σ | | Simple Slopes of Resp over UA+1σ and UA−1σ | | |




*** $p < 0.001$, ** $p < 0.01$; unstandardized coefficients are shown.

## 6. Conclusions

This study constructs four dimensions of blockchain's perceived benefits for SCRM and explores the influence mechanism of these benefits on the intention to use blockchain in SCRM, and we draw the following conclusions:

First, our study shows that blockchain technology has a significant positive impact on the perceived usefulness of supply chain resilience and responsiveness. Blockchain technology is conducive to enhancing the resistance of supply chain risks, which in turn benefits the supply chain. Blockchain traceability enhances supply chain responsiveness and resilience by improving the accuracy and trustworthiness of the overall supply chain information, reducing supplier opportunism, and making the entire supply chain more robust. Transparency enhances supply chain responsiveness and resilience by increasing the openness and availability of information on the blockchain and reducing fraud. Information sharing enhances supply chain responsiveness and resilience by advancing comprehensiveness, immediacy, security, and consistency of information, improving operational efficiency, and reducing potential conflicts over specific transactions. Decentralization reduces the complexity and uncertainty of the transaction process, improves the ability to record and update data in real time, and weakens the importance of a single node in the supply chain, thus enhancing supply chain responsiveness and resilience.

Second, the perceived usefulness of the two types of capabilities is closely related to the intention to adopt blockchain technology. Previous studies on blockchain adoption have found that improvements in job performance driven by technology can increase the intention to use it [15–18]. We concretize this deterioration  into the two aspects of supply chain resilience and responsiveness and verify it. The mediation analysis results show that the positive impact of blockchain technology on SCRM capabilities greatly improved the intention of supply chain managers to adopt it.

Third, there are differences in the moderating effect of uncertainty avoidance cultural values on the relationship between the perceived usefulness of blockchain in supply chain resilience and responsiveness, and intention to use it. People with different levels of uncertainty avoidance are more concerned about supply chain responsiveness, while there is no significant difference in the perceived usefulness of supply chain resilience. One possible explanation is that supply chain managers focus more on risks that occur more frequently. Compared with supply–demand coordination risks, disruption risks involve a series of incidents with low probability and high impact [30]. Meanwhile, the results also reflect managers' lower concern for disruption risks and their reluctance to make non-cost-effective investments [30].

## 7. Implications and Limitations

### *7.1. Theoretical Contributions*

This study promotes a theoretical understanding of blockchain technology in SCRM. First, this study explores the application of blockchain in the supply chain, theoretically supplementing research on "double-chain fusion," which posits that one strong predictor of actual adoption behavior is the perception of the potential benefits of new technologies. We concretize blockchain's advantages for the supply chain into four perceived benefits: traceability, information sharing, transparency, and decentralization.

Second, this study enriches the TAM. From the perspective of SCRM, we define and expand the dimensions of perceived usefulness. Although the perceived usefulness of the TAM is classical, attention should be paid to the validity of variable measurement when applying usefulness to organizations' technology adoption scenarios. As supply chain risks can be broadly divided into two categories: disruption risks and supply–demand coordination risks, we extend the perceived usefulness into two dimensions of supply chain resilience and supply chain responsiveness, enriching the research on technology adoption and SCRM.

Third, our study expands the research on cultural values. From the perspective of uncertainty avoidance cultural values, this study explains the differences in adoption among countries at the individual level according to the different levels of individual beliefs in cultural values, which enriches research on the impact of social culture on individual behavior.

### *7.2. Management Implications*

This study has several important management implications. First, we provide a framework to understand blockchain for organizations and managers. Assessing the potential impact of new technologies can help maintain competitive advantages. Managers can evaluate the usefulness of blockchain technology by identifying the four blockchain benefits: blockchain can track the flow of raw materials and products across supply chains, can enhance the transparency of supply chain networks, can ensure secure real-time information sharing, and can ensure system security and enhance trust with decentralization. Meanwhile, this study also establishes a strong link between blockchain and supply chain risk resistance, which can help managers investigate the spillover of blockchain technology from a risk management perspective, that is, the role of blockchain in building supply chain resilience and responsiveness. Supply chain responsiveness can help companies gain a competitive advantage in a volatile market, and ahigh resilience supply chain can recover quickly from disruption to resume normal operations.

Second, our findings are particularly useful for technology adoption in multinational organizations, especially in teams of people from different nationalities. Managers should be aware of the influence of national cultural values on technology adoption. The role of blockchain in resisting risk has prompted those who seek certainty to actively adopt the technology. Considering the difference in the moderating effect of uncertainty avoidance on the intention to use, we believe that this implies a disregard for supply chain resilience by managers. Managers should realize that supply chain resilience and responsiveness are two types of capabilities of different natures, which are crucial for production and operation. Compared to the supply–demand problems that can be solved to return to normal operations, the risk of disruption may deal a fatal blow to the enterprise. Enhanced supply chain resilience can mitigate the damage caused by unforeseen incidents.

### *7.3. Limitations and Future Research*

Although our data verified the hypotheses to the greatest extent, some limitations remain. First, this study only assesses supply chain managers' perceptions of the usefulness of blockchain, especially the perceived value of blockchain technology among supply chain managers before adoption. However, blockchain technology has some limitations, such as its irreversibility, weak security, low privacy, and substantial computational power. We also look forward to the wide adoption of blockchain technology and metaverse [72], and future research can further analyze the role of technology in improving supply chain risk resistance through both perceived benefits and risks, and even negative news [73].

Second, this study intended to extend the perceived usefulness of blockchain to SCRM, but there are still other supply chain capabilities that can help companies deal with risks. Ivanov and Dolgui [74] argue that supply chain robustness can improve supply chain risk tolerance without changing the organizational structure. Future research could explore the perceived usefulness of blockchain in areas such as supply chain relationship management.

Finally, our study verifies that uncertainty avoidance cultural values can explain the differences in the intentions of managers across countries to adopt blockchain technology to some extent. In fact, there are other variables that affect the differences in adoption, even acting as obstacles, such as regulatory uncertainty and pressure on technology costs. Future research can further explain the differences in adoption intentions based on macro national institutions and laws, as well as other micro-variables that describe individual differences.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Shanghai University.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data are available upon request from the authors.

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

## Appendix A

**Table A1.** Summary of research on blockchain in the supply chain.

| Authors | Blockchain benefits | Methods | Summary |
|---|---|---|---|
| Roeck, Sternberg and Hofmann [38] | Transparency, disintermediation, trust | Multiple case studies | Distributed ledger technology (DLT) had nine effects on transaction cost economics in supply chains via DLT-enhanced (1) transparency, (2) trust, and (3) disintermediation. |
| Babich and Hilary [35] | Visibility, aggregation, validation, automation, resiliency | Conceptual | The authors identified five key strengths, the corresponding five main weaknesses, and three research themes of applying blockchain technology to operations management. |
| Baharmand, et al. [75] | Traceability, transparency, visibility, trust | Case study | This research outlined a validated list of drivers and barriers and provided evidence concerning blockchain that had shown added value to improve humanitarian supply chains' transparency and trust in practice. |

| | | | |
|---|---|---|---|
| Wang, Singgih, Wang and Rit [55] | Traceability, transparency, information sharing, decentralization, trust, security, automation | Expert interview and cognitive mapping | This research ensured blockchain's perceived benefits to supply chains and captured a number of challenges to blockchain's further diffusion. |
| Hastig and Sodhi [3] | Supply chain traceability | Thematic analysis | This research ascertained five business requirements and six critical success factors for the implementation of traceability systems. |
| Shen, Dong and Minner [41] | Supply chain transparency | Mathematical modeling | This study found that if the number of novice consumers was large enough, then selling through a permissioned blockchain technology retailer was an effective anti-copycat solution. |
| Wang, Zheng, Jiang and Tang [40] | Transparency, data sharing, decentralization, trust, security, anonymity | Mathematical modeling | This research provided a blockchain-based solution to data sharing in SCM and developed the EVSI (the expected value of sample information) and EVI (the expected value of the information) methods to accommodate different data-sharing scenarios. |
| Saberi, Kouhizadeh, Sarkis and Shen [4] | Traceability, transparency, decentralization, security, auditability, trust, smart execution | Conceptual | This study critically examined the potential application of blockchain technology and smart contracts in supply chain management and summarized four potential barriers to adoption. |
| Lohmer, Bugert and Lasch [39] | Traceability, data sharing, decentralization, supply chain visibility, security | An agent-based simulation study | The results indicated significant improvement in supply chain resilience in efficient blockchain technology-based collaboration. |
| Xiong, Lam, Kumar, Ngai, Xiu and Wang [60] | Traceability, transparency | An event study | The results demonstrated the role of blockchain-enabled supply chains (BESCs) in mitigating the negative impact caused by the COVID-19 pandemic. Moreover, the mitigating role of BESCs was more pronounced for firms with lean and complex supply chains. |
| Centobelli, Cerchione, Vecchio, Oropallo and Secundo [37] | Traceability, transparency, trust | A single in-depth case study | The proposed Triple Retry framework was used to evaluate the impact of blockchain technology on the circular supply chain. |
| Kouhizadeh, Saberi and Sarkis [54] | Transparency, decentralization, security, smart contracts, improved efficiency | DEMATEL methodology | The four different barrier categories investigated in this study for blockchain adoption in sustainable supply chains were initial and exploratory. |
| Shi, Yao and Luo [36] | Traceability, transparency, decentralization, smart contract, low information sharing cost | Literature review | Examining the value of different blockchain features in operations management, this further reviewed the related works on platform operations with blockchain technologies. |

**Appendix B**

**Table A2.** Review of theories and innovative variables used in recent blockchain adoption literature.

| Source | Object of Study | Country | Theoretical Foundation | Innovative Variables | Methods |
|---|---|---|---|---|---|
| Janssen, Weerakkody, Ismagilova, Sivarajah and Irani [45] | 31 articles on blockchain adoption | / | Koppenjan and Groenewegen's framework | A process–institution–market–technology (PIMT) framework is proposed | Literature review |
| Kamble, Gunasekaran, Kumar, Belhadi and Foropon [14] | 289 respondents from 181 companies in Mumbai and Bangalore | Two cities in India | TAM, TOE framework | Information security | Questionnaire survey (SEM and Bayesian Network Analysis) |
| Queiroz and Fosso Wamba [16] | 344 Indian and 394 American supply chain professionals with at least 3 years of experience | India and USA | A slightly modified UTAUT | Blockchain transparency, trust | Questionnaire survey (SEM) |
| Karamchandani, Srivastava and Srivastava [15] | 258 middle and senior managers in the service industry with blockchain knowledge from the LinkedIn platform | / | An extended TAM | Perceived usefulness of enterprise blockchain in the customer relationship, information quality, service quality, supply uncertainty, mass customization, and delivery reliability | Questionnaire survey (SEM) |
| Wong, Leong, Hew, Tan and Ooi [20] | 194 SMEs from Malaysia | Malaysia | TOE framework | Relative advantage, complexity | Questionnaire survey (SEM and Artificial Neural Network Analysis) |
| Fosso Wamba, Queiroz and Trinchera [12] | 344 Indian and 394 American supply chain professionals with at least 3 years of experience | India and USA | TAM, UTAUT | Knowledge sharing and blockchain transparency | Questionnaire survey (SEM) |
| Queiroz, Fosso Wamba, De | 184 Brazilian operations and | Brazil | A modified version of UTAUT | Trust | Questionnaire survey |

| | | | | | |
|---|---|---|---|---|---|
| Bourmont and Telles [17] | supply chain professionals | | | | |
| Kamble, Gunasekaran and Arha [13] | 181 supply chain practitioners with at least 2 years of experience from 102 companies | India | TAM, TPB, TRI | / | Questionnaire survey |
| Wong, Tan, Lee, Ooi and Sohal [18] | Logistics and supply chain management staff of 157 enterprises | Malaysia | UTAUT | Technology affinity; Technology readiness | Questionnaire survey |

## Appendix C

**Table A3.** Questionnaire items.

| Construct | Label | Measures | Adapted From |
|---|---|---|---|
| Traceability | Trac1 | Blockchain can help your company to know the sources of your raw materials. | Cousins, Lawson, Petersen and Fugate [50] |
| | Trac2 | Blockchain can help your company to track the processes involved in producing the product throughout the supply chain. | |
| | Trac3 | Blockchain can help your company to trace the origins of your purchases through the entire supply chain. | |
| | Trac4 | Blockchain can help your company to track the environmental performance of your complete supply chain. | |
| | Trac5 | Blockchain can help your company to know what chemicals or elements are in your purchased components. | |
| Information Sharing | IS1 | Your company expects other companies in the supply chain to use blockchain to provide any information that might help your company. | Cai, Jun and Yang [64] |
| | IS2 | Your company expects other companies in the supply chain to use blockchain to provide proprietary information that is helpful to your company. | |
| | IS3 | Your company expects other companies in the supply chain to use the blockchain to inform it about all events or changes that may affect the company. | |
| | IS4 | The blockchain can help your company to regularly exchange information about supply and demand forecasts with other companies in the supply chain. | |
| | IS5 | The blockchain can help your company to frequently exchange information with other companies in the supply chain. | |
| Transparency | Trans1 | I believe blockchain enabled-supply chain processes would be transparent. | Fosso Wamba, Queiroz and Trinchera [12] |
| | Trans2 | I believe supply chain stakeholders will enable my company to have a better understanding of how blockchain-enabled supply chain applications work. | |
| | Trans3 | I believe supply chain stakeholders will provide my company with in-depth knowledge of blockchain applications in the supply chain. | |
| | Trans4 | I believe I will have opportunities to provide feedback on blockchain-enabled supply chain applications. | |
| Decentralization | Dec1 | I believe there is no central entity in the blockchain. | |
| | Dec2 | I believe that execution authority will be distributed to all nodes of the blockchain. | |
| | Dec3 | I believe that each node of the blockchain will be allowed to record transactions. | |
| | Dec4 | I believe that companies on the blockchain will be fully empowered to use the blockchain. | |
| | Dec5 | I believe that the information on the blockchain will be verified by the majority of companies of blockchain. | |

| | | | |
|---|---|---|---|
| PU of BC in supply chain resilience | SCR1 | With the use of blockchain, your company's supply chain will be more capable of adequately responding to unexpected disruptions by quickly restoring its product flow. | Gölgeci and Kuivalainen [33] |
| | SCR2 | With the use of blockchain, your company's supply chain can more quickly return to its original state after being disrupted. | |
| | SCR3 | With the use of blockchain, your company's supply chain can move to a newer and more desirable state after being disrupted. | |
| | SCR4 | With the use of blockchain, your company's supply chain can be better prepared to deal with the financial consequences of potential supply chain disruptions. | |
| | SCR5 | With the use of blockchain, your company's supply chain will be more capable of maintaining a desired level of control over structure and function at the time of disruption. | |
| PU of BC in supply chain responsiveness | Resp1 | With the use of blockchain, your company's supply chain can respond more quickly and effectively to changing customer and supplier needs than your competitors. | Yu, Chavez, Jacobs, Wong and Yuan [34] |
| | Resp2 | With the use of blockchain, your company's supply chain is able to respond more quickly and effectively to your competitors' changing strategies than other competitors. | |
| | Resp3 | With the use of blockchain, your company's supply chain can develop and market new products more quickly and effectively than your competitors. | |
| | Resp4 | With the use of blockchain, your company's supply chain will compete effectively in most markets. | |
| | Resp5 | By strengthening the cooperative relationship with partners through the blockchain, you will increase your supply chain responsiveness to market changes. | |
| Uncertainty Avoidance | UA1 | Rules and regulations are important because they inform workers about what the organization expects of them. | Srite and Karahanna [66] |
| | UA2 | Order and structure are very important in a work environment. | |
| | UA3 | It is important to have job requirements and instructions spelled out in detail so that people always know what they are expected to do. | |
| | UA4 | It is better to have a bad situation that you know about, than to have an uncertain situation that might be better. | |
| | UA5 | Providing opportunities to be innovative is more important than requiring standardized work procedures. | |
| | UA6 | People should avoid making changes because things could get worse. | |
| Intention to use blockchain | IU1 | Your company would like to use blockchain technology to solve future issues. | Autry, Grawe, Daugherty and Richey [58] |
| | IU2 | Your company will want to use blockchain technology to solve problems if it is effective. | |
| | IU3 | Your company intends to use blockchain technology wherever possible to address key concerns. | |

## Appendix D

**Table A4.** Demographic profile (*N* = 203).

| | China | | USA | |
|---|---|---|---|---|
| | **n** | **%** | **n** | **%** |
| **Gender** | | | | |
| Male | 47 | 48.5 | 54 | 50.9 |
| Female | 50 | 51.5 | 52 | 49.1 |
| **Age** | | | | |
| 21–30 | 45 | 46.4 | 13 | 12.3 |
| 31–40 | 47 | 48.5 | 54 | 50.9 |
| 41–50 | 5 | 5.2 | 28 | 26.4 |
| 51–60 | 0 | 0 | 8 | 7.5 |

| | | | | |
|---|---|---|---|---|
| 61+ | 0 | 0 | 3 | 1.9 |
| **Education** | | | | |
| Bachelor's degree | 86 | 88.7 | 68 | 64.2 |
| Master's degree | 11 | 11.3 | 34 | 32.1 |
| Doctorate degree | 0 | 0 | 4 | 3.8 |
| **Position** | | | | |
| Junior management (assistant manager of technical department, system analysis engineer) | 46 | 47.4 | 13 | 12.3 |
| Middle management or head of department | 32 | 33.0 | 68 | 64.2 |
| Senior management or director | 16 | 16.5 | 23 | 21.7 |
| Others | 3 | 3.1 | 2 | 1.8 |
| **Years of Work Experience** | | | | |
| 1–2 | 8 | 8.2 | 11 | 10.4 |
| 3–5 | 48 | 49.5 | 59 | 55.7 |
| 6–10 | 38 | 39.2 | 26 | 24.5 |
| 11–15 | 2 | 2.1 | 8 | 7.5 |
| 16+ | 1 | 1.0 | 2 | 1.9 |
| **Field of Work** | | | | |
| Production management | 17 | 17.5 | 19 | 17.9 |
| Purchase management | 18 | 18.6 | 15 | 14.2 |
| Logistics management | 20 | 20.6 | 12 | 11.3 |
| Marketing management | 16 | 16.5 | 26 | 24.5 |
| Quality management | 5 | 5.2 | 6 | 5.9 |
| Inventory management | 5 | 5.2 | 1 | 0.9 |
| Finance management | 4 | 4.1 | 11 | 10.4 |
| Information management | 11 | 11.3 | 16 | 15.1 |
| Others | 1 | 1.0 | | |
| **Firm Size (number of employees in firm)** | | | | |
| 0–100 | 8 | 8.2 | 10 | 9.4 |
| 101–500 | 49 | 50.5 | 51 | 48.1 |
| 501–1000 | 31 | 32.0 | 40 | 37.7 |
| 1001–2000 | 4 | 4.1 | 3 | 2.8 |
| 2001+ | 5 | 5.2 | 2 | 1.9 |
| **Industry** | | | | |
| Agriculture, forestry, and fishing | 0 | 0 | 3 | 2.8 |
| Mining and quarrying | 0 | 0 | 5 | 4.7 |
| Manufacturing | 42 | 43.3 | 44 | 41.5 |
| Construction | 2 | 2.1 | 5 | 4.7 |
| Wholesale and retail trade; repair of motor vehicles and motorcycles | 7 | 7.2 | 9 | 8.5 |
| Transportation and storage | 20 | 20.6 | 3 | 2.8 |
| Accommodation and food service activities | 1 | 1.0 | 3 | 2.8 |
| Information and communication | 9 | 9.3 | 15 | 14.2 |
| Financial and insurance activities | 1 | 1.0 | 8 | 7.5 |
| Professional, scientific, and technical activities | 1 | 1.0 | 3 | 2.8 |
| Electricity, gas, steam, and air conditioning supply | 5 | 5.2 | 0 | 0 |
| Administrative and support service activities | 2 | 2.1 | 2 | 1.9 |
| Education | 2 | 2.1 | 5 | 4.7 |
| Human health and social work activities | 2 | 2.1 | 0 | 0 |
| Arts, entertainment, and recreation | 2 | 2.1 | 0 | 0 |
| Public administration and defense; compulsory social security | 1 | 1.0 | 0 | 0 |
| Other service areas | 0 | 0 | 1 | 0.9 |

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