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Original scientific paper

Humanitarian Supply Chain Agility: A Blockchain Integration Perspective

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Abstract: The requirement to improve the effectiveness of humanitarian aid has recently received increased attention. Even though some literature has acknowledged the key factors to success for humanitarian supply chain, such as cooperation, information sharing, resilience, how to create an agility supply chain in the disaster context has not been studied. To address this theory and practical gap, we construct the characteristic elements of the blockchain and propose a theoretical model to empirically study the impact of blockchain technology on humanitarian supply chain agility. Primary data are collected from 300 participants who work for Chinese humanitarian organizations. Blockchain technology further improves the agility of humanitarian supply chains through trust. All hypotheses are confirmed, with the transparency having the greatest impact on the humanitarian supply chain agility. Our study provides theoretical and empirical basis for further research on the humanitarian supply chain flexibility. We also note the limitations of our study and offer future research direction.

Keywords: blockchain technology; humanitarian supply chain; transparency; trust

1 INTRODUCTION

Around the world, natural disasters and man-made safety accidents are intertwined. Human life and property are severely affected by disasters of all kinds which include earthquakes, floods and terrorist attacks. For instance, extreme rainstorms in China's Henan province led to 302 fatalities in July 2021. Humanitarian organizations are expected to deliver the food, medicine, clothing and other donations on time. However, the supply side is complex. Demand side behavior is uncertain and network nodes are at risk of disruption [1]. Therefore, the humanitarian supply chain agility is facing a series of challenges with uncoordinated supply and demand. Blockchain technology is expected to improve the humanitarian supply chain agility. Blockchain has a better internal institutional design. The bitcoin concept proposed by Satoshi Nakamoto in 2008 marked the birth of blockchain. Blockchain is a shared database and distributed ledger made up of smart contracts, consensus algorithms, cryptography, data storage and more. Distributed storage technology effectively ensures the accuracy and traceability of information transmission. At the same time, data structure consensus, trust consensus and incentive consensus ensure the integrity and credibility of node information. In addition, smart contract technology ensures the efficiency of the data exchange process by automatically executing agreed procedures based on trusted and tamper proof data. The introduction of blockchain technology into humanitarian supply chains is bound to make them more resilient and agile. Since some researches explained that the characteristics of the blockchain have positive impact on the relief supply chain, we focus our study on the issues such as "what determines an organization's information processing needs", "which strategies affect an organization's information processing capabilities", and "how to match the relationship between information processing needs and information processing capabilities". These have become an important theoretical perspective for guiding organizational design and inter organizational relationship management. We derive a theoretical framework based on resource-based view (RBV) and introduce a mediation model to answer the above questions. The results show that blockchain technology significantly improves the agility of the humanitarian supply chains through swift trust. Our results are consistent with the special operational patterns of the humanitarian supply chains. This work has made the following main contributions:

• Blockchain technology can improve the agility of the humanitarian supply chain. This improvement is mainly reflected through swift trust.

• This study further finds which characteristics of blockchain affect the agility of humanitarian supply chains. The results confirm the traceability, transparency and immutability of blockchain technology enhance the flexibility of supply chain. Previous studies in this field are lacking.

The remainder of the paper is arranged as follows. Section 2 summarizes the literature on blockchain, supply chain and its agility. Section 3 proposes theoretical models and hypothetical designs. Section 4 tests a reliability and validity analysis of the variables. Section 5 empirically verifies the research hypothesis and completes the robustness test. Section 6 offers concluding comments.

2 LITERATURE REVIEW

The humanitarian supply chain has encountered certain issues, including a lack of information sharing and transparency. Some characteristics of blockchain technology can alleviate these problems. Therefore, an increasing number of scholars combine blockchain and supply chain. Scholars find that blockchain technology effectively promotes the operation of the supply chain. Despite the advantages that blockchain brings to the supply chain, there are still some problems in its practical application, which make managers to not adopt blockchain technology.

2.1 Blockchain and the Humanitarian Supply Chain

Humanitarian supply chains encounter two common problems. First of all, there is a lack of information sharing and flexibility in the supply chain. Especially at a low level of cooperation, the flexibility to respond to demand is poor [2]. Second, the humanitarian supply chain is a centralized information system, which depends on key nodes. If key

nodes fail, the entire supply chain will become vulnerable [3]. Therefore, humanitarian supply chains are severely disrupted by centralized insecurity, trust and collaboration [4], mainly manifested in: (1) difficulty in integrating goods, finance and information flow in the supply chain; (2) Lack of clear processes and rules [5]; (3) The total inventory cost remains high; (4) The rate of spoilage increases when food is supplied to disaster areas [6]. A lot of faith is being placed in blockchain to solve these problems. Many scholars pay attention to the application of blockchain technology in the humanitarian supply chain. Up to a point, some authors believe blockchain has the characteristics of transparency, openness and increased trust [7]. These characteristics are the important reasons why humanitarian supply chain managers adopt blockchain technology. Blockchain technology can help save costs and make rescue operations more effective. Blockchain can improve humanitarian relief operations through protected data sharing, transparency of supply chain and effective information dissemination. Baharmand et al. [8] think the blockchain can reduce total inventory and unnecessary waste. In addition, the Casino et al. [9] contend blockchain can also improve work efficiency and product quality. Saberi et al. [3] believe blockchain can enhance the resilience and security of the supply chain and contribute to the sustainable development of supply chain. When combined with RFID and the Internet of Things, the blockchain can facilitate the entire supply chain [10, 11]. Although blockchain is a hot topic in recent years, it still faces various challenges and problems in the application of supply chain. As far as blockchain based application obstacles are concerned, they mainly focus on technology, organization and the environment. Some scholars focus on technical barriers [12]. The lack of professional skills, technical complexity and application risks will bring great obstacles to the application of blockchain while Baharmand and Comes [13] took into account inter-organizational barriers such as the proportion of capital allocated. Each node in the supply chain is unwilling to bear most of the costs. Some scholars believe inter-organizational barriers are most suitable for blockchain technology as well [14]. In addition, there are legal environment issues. Blockchain is an emerging combination technology, which means that the field lacks a comprehensive legal system. Supervision, regulations and other issues will profoundly affect decision makers. Although a large number of scholars study blockchain and the humanitarian supply chain, there is still a gap in the field of using empirical research to analyze which characteristics of blockchain affect the agility of humanitarian supply chain. Few scholars have studied the characteristic elements of the blockchain. Meanwhile, few researchers empirically tested such factors in the humanitarian supply chain context.

2.2 Supply Chain Agility

Business supply chain agility is an organization's response to market changes and customer demands in the face of competition, complex, dynamic and uncertain business environment [15]. The humanitarian supply chain has certain similarities with commercial supply chain. The humanitarian supply chain agility refers to the flexibility and ability to respond to the unpredictable changes of victims' needs [16]. In a highly uncertain organizational environment, supply chain agility is considered an important factor for organizational success [17]. Affected by enterprises' inaccurate grasp of the market and positioning bias, nearly three quarters of the global enterprises suffer from supply chain disruption every year, such as demand fluctuations and production line failures. Similarly, in the humanitarian supply chain, there are some problems, for example, the uncertainty of victims and the instability of supply. Timely and effective assistance helps to identify victims and strengthen communication and collaboration among stakeholders [4, 18-20]. This timely and effective assistance can be reflected in the agility of the supply chain [21].

3 RESEARCH METHODOLOGY

From the organizational information process theory (OIPT) conceptualized by Thompson [22], the relief organization needs to process information with different levels of uncertainty in disasters, which can help the organization achieve a competitive advantage. Hence, uncertainty drives the need for information processing capacity, and for the information technology to supply the core competition for the humanitarian supply chain. Owing to improvement of information visibility, decision-making becomes more effective and swift. When disaster occurs, decision-makers need to process data efficiently and draw the relief plan rapidly. Fortunately, the blockchain can respond quickly through broadcasting the information as the need, the supply and the disasters in the chain, which enhances the organizational performance [23].

3.1 Hypotheses

3.1.1 Traceability of Blockchain Technology and the Agility of the Supply

Blockchain technology is characterized by traceability. Traceability is created by the ability to communicate with stakeholders in an operational supply chain [24]. Blockchain traceability can trace the current or historical status of supply chains. Especially in the humanitarian supply chains, the regulatory requirements for products are more stringent. Ozdemir et al. [14] believe the traceability of blockchain is helpful for the humanitarian supply chain management. Through the traceability of the blockchain, managers dynamically monitor the status of products in the supply chain and mitigate the "bullwhip effect" in the supply chain [25]. This paper argues the traceability of blockchain technology improves the humanitarian supply chain agility. The hypothesis is as follows:

Hypothesis 1. In practical operation, we think the traceability of blockchain technology positively influences the humanitarian supply chain agility.

3.1.2 Transparency of Blockchain Technology and Supply Chain Agility

Blockchain technology is characterized by transparency. Influenced by communication technology,

consensus mechanism and data encryption technology at the bottom of blockchain, blockchain has a high degree of transparency, which can reduce the uncertainty of behaviour [2, 3]. The transparency of the blockchain facilitates information sharing [26] and knowledge flow in supply chains. Information sharing is the key to improve supply chain agility [27]. The transparency of blockchain technology helps the humanitarian supply chains be alert to emergency needs and quickly adjust their strategies to minimize losses when circumstances change. The transparency of blockchain can improve the humanitarian relief operations. The following hypothesis is proposed for this research:

Hypothesis 2. In real rescue actions, we think the transparency of blockchain technology positively influences the humanitarian supply chain agility.

3.1.3 Immutability of the Blockchain

Blockchain technology is characterized by immutable data [28]. Therefore, blockchain can enhance the security of supply chain [3]. It helps to gather factual information up and down through the supply chain and enables humanitarian organizations to respond flexibly in emergency situations. In this study, immutability is considered from the perspective of data security, integrity and usefulness. The hypothesis is as follows:

Hypothesis 3. In real rescue actions, immutability of blockchain technology positively influences the humanitarian supply chain agility.

3.1.4 Mediation of Trust

Trust is vital to any organization. As PWC says, convenience and cost savings are the guiding light, but in the end it is trust that keeps the economy going and growing. Trust has four dimensions [8]: Commitment, company, ability and speed. At present, the research on blockchain mainly focuses on commitment and speed. Many scholars have demonstrated blockchain has a significant impact on trust [29]. Blockchain technology can enhance the trust between partners in the humanitarian environment by maintaining the reliability and validity of data [7]. At the same time, the high trust in the humanitarian supply chain significantly improves the humanitarian supply chain agility, which is reflected in the active cooperation among the nodes [29]. Therefore, we assume trust plays a mediating role in the process of blockchain technology improving supply chain agility. The hypothesis can be described as follows. In real rescue actions, we think,

Hypothesis 4. the traceability of blockchain technology positively influences supply chain agility through trust.

Hypothesis 5. The transparency of blockchain technology positively influences supply chain agility through trust.

Hypothesis 6. The immutable nature of blockchain technology positively influences supply chain agility through trust.

3.2 Theoretical Model

Based on the above assumptions, we construct a theoretical framework. Traceability, transparency and immutability of blockchain technology are independent variables, the humanitarian supply chain agility is dependent variable and trust is intermediary variable. The theoretical framework is shown in Fig. 1.

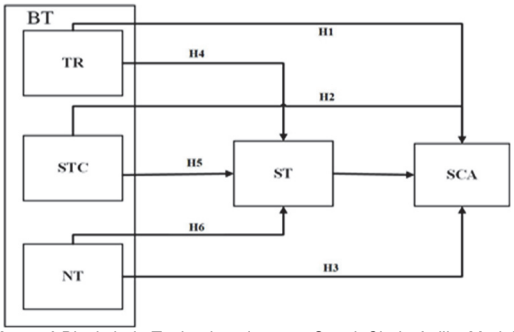

Figure 1 Blockchain Technology Impacts SupplyChain Agility Models
NT = Immutability; TR = traceability; STC = transparency;
ST = trust; SCA = humanitarian supply chain agility

4 RESEARCH DESIGN AND THE SMALL SAMPLE TEST

4.1 Research Design

Based on the previous work [7, 17, 26, 29], we design a five-point scale with 1 = Strongly disagree, 2 = disagree, 3 = Hardly agree, 4 = agree, 5 = Strongly agree. We develop the questionnaire based on the former study mainly by Dubey. See the variables and reference source from Tab. 1.

Table 1 Variables and Reference Source

Variables	Items	Reference Source
NT	Immutability	[32]
TR	Traceability	[30] [31]
STC	Transparency;	[26]
ST	Trust	[32] [33] [2]
SCA	Supply chain agility	[7] [15, 34]

In order to test the research framework and the hypotheses, we need to collect data, pretest the scale. Firstly, we invited five experienced researchers and the professional experts to provide their suggestions regarding the questionnaire. Based on these advices, we revised the items. A total of 22 items are included in the last questionnaire (excluding the description items). Secondly, we test the discriminant of the measurement instrument with 100 responses from emergency logistics enterprises (pharmaceutical companies, and always these companies undertake the research and development, production, and transportation of drugs).

4.2 Reliability Analysis

Firstly we measure the mean, the variance and the Cronbach α for each item with the help of SPSS 25. Since

all $\alpha > 0.7$, the questionnaires are reasonable. In other words, the items included in immutability, traceability, transparency, trust and humanitarian supply chain agility are clearness, appropriateness for the study. The details are shown in Tab. 2.

Table 2 Reliability Analysis

Items	N	mean	variance	Alphas	Items	N	mean	variance	Alphas
NT1	100	4.47	0.454		ST1	100	4.44	0.350	
NT2	100	4.26	0.497	0.706	ST2	100	4.36	0.374	0.702
NT3	100	4.44	0.471		ST3	100	4.55	0.371	
TR1	100	4.52	0.333		ST4	100	4.56	0.350	
TR2	100	4.51	0.394	0.709	SCA1	100	4.38	0.379	
TR3	100	4.36	0.455		SCA2	100	4.38	0.420	
STC1	100	4.13	0.943		SCA3	100	4.53	0.353	0.710
STC2	100	4.21	0.531		SCA4	100	4.32	0.503	
STC3	100	3.73	1.290	0.795	SCA5	100	4.33	0.486	
STC4	100	4.25	0.735		SCA6	100	4.54	0.372	
STC5	100	4.26	0.437						

Note: NT: immutability; TR: traceability; STC: transparency; ST: trust; SCA = humanitarian supply chain agility

4.3 Factor Analysis

We then verified the integrity and structure of the measurement instrument by factor analysis. As shown in Tab. 3 and Tab. 4, the questionnaire is suitable for factor analysis (KMO = 0.729). The four independent variables after rotation are higher than 0.5.

Table 3 KMO and Bartlett Test of Sphericity

KMO		0.729
Bartlett Test of Sphericity	Approx. Chi-Square	421.543
	df	105
	sig	0.000

Table 4 Rotated component matrix

Items	1	2	3	4
NT1	0.777			
NT2	0.658			
NT3	0.879			
TR1		0.712		
TR2		0.801		
TR3		0.811		
STC1			0.768	
STC2			0.717	
STC3			0.817	
STC4			0.741	
SCT5			0.530	
ST1				0.648
ST2				0.625
ST3				0.738
ST4				0.736

Note: extraction method is principal component analysis method, rotation method is Caesar normalization maximum variance method.

In the pretest, the measurement instrument is based on the previous researchers, the brainstorming of the research team and the background of the humanitarian supply chain. According to the previous researchers, the reliability and validity of this scale should be good. However, the reliability and validity of transparency in the actual questionnaire survey are extremely low. Therefore, the transparency dimension of the original scale needs to be rethought. In the previous researches on transparency of the humanitarian supply chain, we regularly share our operation plan (distribution and storage plan), our partners regularly collect strategic information related to target areas, our partners often share strategic information, our local partners share strategic information about government regulations and other useful information. In the final scale of this study, more consideration is given to the cultural background. We describe in detail from the financial, market and operational aspects, stating that each node of the blockchain can disclose the sales situation. Blockchain nodes can share sales plans with each other. Blockchain nodes can disclose profits. Blockchain nodes can share production capacity with each other. Blockchain nodes can share the utilization degree of related resources with each other. Such a description may be easier to understand. The reliability and validity of supply chain transparency have been significantly improved.

5 EMPIRICAL DATA ANALYSIS

5.1 Data Collection

The questionnaire in this paper began to collect data in September 2021 and was completed in early October 2021. The questionnaire contains an invitation letter and introduction that displayed the purpose of the research and made a detailed explanation for proper terms, such as blockchain technology. During this period, more than 700 respondents participated. 300 questionnaires of the entire content are valid, an efficiency of 43%. The reliability and validity were basically the same as the pretest. The values of Alpha and KMO are both higher than 0.7.

5.2 Common Method Bias

We mainly use two methods to test the common method deviation problem. On the one hand, we adopt the split measurement method. In the test samples, we independently test the effect of ST on SCA. Undoubtedly, the result is significant. On the other hand, we conduct the single-factor test. The principal component analysis successfully extracts four dimensions without setting any of them. The largest total variance of the factor is explained

by 24.768%. Based on the above, our study is not able to be affected by common method bias.

5.3 Regression Analysis and Hypothesis Test

We test the impact of traceability, transparency, and immutability of blockchain technology on the humanitarian supply chain agility with the help of SPSS 25. The results are shown in Tab. 4 and Tab. 5. Meanwhile, we measure the variance inflation factor (VIF). The maximum variance inflation factor is 1.17, which is lower than the critical value of 3. Therefore, we argue multi-collinearity is not a major issue in our study. From Tab. 5, three hypotheses (1, 2, 3) are supported. The result shows the importance of blockchain technology in the humanitarian supply chain agility and further reveals which characteristics of blockchain affect the agility of supply chain. (through three characteristics of blockchain technology: traceability (β = 0.178, P = 0.001), transparency (β = 0.303, P = 0.000) and immutability (β = 0.147, P = 0.007). From Tab. 6, the result supports hypotheses 4, 5, and 6. Among them, trust has an indirect effect of 0.04, 0.07 and 0.04 respectively. The result shows the traceability, transparency, and immutability of blockchain technology can improve the humanitarian supply chain agility through trust. Trust can effectively improve the response of the humanitarian supply chain to emergency needs. This answers our second question (how does blockchain improve the agility of humanitarian supply chain).

Table 5 Regression Analysis

Regression equation (N = 300)			Fitting index			Coefficient significance		
Model	Dependent variable	Independent variable	R^2	F	P	β	t	p
M1	ST	TR	0.018	6.500	0.011	0.146	2.549	0.011
	SCA	TR	0.152	27.718	0.000	0.178	3.298	0.001
		ST				0.330	6.121	0.000
M2	ST	STC	0.139	49.176	0.000	0.376	7.012	0.000
	SCA	STC	0.200	38.299	0.000	0.303	4.328	0.000
		ST				0.242	5.419	0.000
M3	ST	NT	0.016	5.913	0.016	0.139	2.432	0.016
	SCA	NT	0.142	25.704	0.000	0.147	2.713	0.007
		ST				0.335	6.193	0.000

Note: NT: immutability; TR: traceability; STC: transparency; ST: trust; SCA: humanitarian supply chainagility.

Table 6 Analysis of mediating effects

Path	The indirect effect	BootSE	BootLLCI	BootULCI	Ind/Total
TR → ST → SCA			0.0087	0.0833	0.213558
STC → ST → SCA	0.0661	0.0224	0.0278	0.1157	0.231038
NT → ST → SCA	0.0352	0.015	0.0068	0.0657	0.241261

5.4 Robustness Test

Due to the influence of the nature of the questionnaire data in this study, two methods are used for the robustness test: replacement of model test method and robust regression (as shown in Tab. 7). The data in this paper are tested for robustness by replacing the model test method. Stata 16 is used to test the Tobit model in robustness tests. Statistical results of all likelihood ratio reject the null hypothesis that the explanatory variable coefficient is zero. All p-values are significant at the level of 0.01. Therefore, all the results support our hypothesis. The robustness regression is conducted, which is consistent with the significance of the Tobit model. The direction of the coefficients remains the same. The standard error has barely changed.

Table 7 Tobit regression and robustness regression

Paths	Tobit regression		Robust regression	
	β	Std. Err.	$\hat{\beta}$	Std. Err.
TR→SCA	0.196(P=0.000)	0.049	0.206(P=0.000)	0.046
TR→ST	0.127(P=0.012)	0.050	0.157(P=0.001)	0.048
STC→ST	0.276(P=0.000)	0.039	0.276(P=0.000)	0.038
STC→SCA	0.220(P=0.000)	0.041	0.204(P=0.000)	0.041
NT→SCA	0.146(P=0.001)	0.043	0.168(P=0.000)	0.041
NT→ST	0.108(P=0.016)	0.044	0.125(P=0.004)	0.043
ST→ SCA	0.350(P=0.001)	0.053	0.322(P=0.000)	0.053

6 RESULTS AND DISCUSSION

6.1 Management Implications

Empirical research is conducted with 300 questionnaires to verify six hypotheses about blockchain technology and supply chain. These results supply us some management insight. Firstly, this study designed a scale to measure the effects of blockchain traceability, transparency and intamability on supply chain agility in humanitarian supply chains. The research makes a significant contribution to the current literature on the humanitarian supply chains and blockchain technology

applications. Since six hypotheses are verified (as shown in Tab. 8), we believe that adopting blockchain technology can always improve the quality level of emergency supplies, making the overall emergency supply chain more efficient and agile. Secondly, this research reveals trust has a mediating effect between blockchain technology and humanitarian supply chain agility as well. The three characteristics of blockchain technology improve supply chain agility through trust. From existing literature and actual cases, trust is important to partners. A good partnership can enhance each other's reputation and increase profits. In this study, it can be seen trust plays a mediating role when the three characteristics of blockchain technology affect the agility of the supply chain. Therefore, it is necessary for every manager in the humanitarian supply chain to realize the importance of trust. Besides, the transparency of blockchain can enhance the agility of emergency supply chain by enhancing swift trust, and transparent and traceable blockchain can effectively mitigate the negative impact of dual moral risks. In the case of traceability, the payment received by upstream suppliers does not need to consider the quality results of downstream suppliers, but only depends on their own quality results, thus having the motivation to improve product quality. Furthermore, the data sharing and transparency of blockchain can play a key role in resource allocation. Especially, the blockchain can reduce the cost of the emergency resource and prevent corruption. Besides, blockchain has high reliability, and the demand for real, consistent, and available data requires the supply chain to enhance data governance. Data quality can seriously affect how the supply chain effectively identifies suppliers and defective materials that cause defects. Higher levels of data quality not only correspond to a higher probability of identifying defective suppliers, but also to more flexible recall of defective products, thereby bringing higher value to the supply chain. The motivation for suppliers to enhance data governance is more aligned with the optimization goal of supply chain agility.

Table 8 Hypothesis test summary

Hypothesis	Hypothesis test	Result
H1	The traceability of BT can improve the humanitarian supply chain agility	Yes
H2	The transparency of BT can improve the humanitarian supply chain agility	Yes
H3	The immutable nature of BT can improve the humanitarian supply chain agility	Yes
H4	The traceability of BT can improve the humanitarian supply chain agility through trust	Yes
H5	The transparency of BT can improve the humanitarian supply chain agility through trust	Yes
H6	The immutable nature of BT can improve the humanitarian supply chain agility through trust	Yes

In the context of frequent natural disasters and public health events, more and more scholars have focused on the agility of the humanitarian supply chain. However, few researchers have attempted to use the characteristics of blockchain technology to improve this problem. This study is believed to contribute to the literature.

6.2 Limitations

This study still has some limitations. This study reveals the mechanism and path of the blockchain in the humanitarian supply chain. However, this study does not analyze the specific application of blockchain technology in the supply chain. For example, design an appropriate consensus mechanism and incentive strategy within the enterprise is a further and valuable work. In fact, the technical framework is the most significant part of designing a block chain. In addition, the solution requires not only technological reform, but also soft resource reform and the integration of the entire supply chain. In the future research, greater consideration needs to be paid to the above restrictions.

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Appendix

The following items in the questionnaire should be checked as the prerequisite assumption: I have some understanding of the application of blockchain.

The scales

1. Traceability of Blockchain technology [9, 31]
- We think blockchain technology can trace the source of material procurement.
- We think blockchain technology can trace the production date of products.
- We think blockchain technology can learn the logistics information of products.

2. transparency of Blockchain technology [26]
- We think each node of the blockchain can disclose the sales situation.
- We think each node of the blockchain can share sales plans with each other.
- We think each node of the blockchain can disclose profits.
- We think each node of the blockchain can share production capacity with each other.
- We think each node of the blockchain can share the utilization degree of related resources with each other.

3. Immutability of Blockchain technology [32]
- We think blockchain technology can store data.
- We think blockchain technology can be used to maintain data security.
- We think blockchain technology can be used to maintain data integrity.

4. Trust [2, 32, 33]
- We think we coordinate supply chain inventory with supply chain partners
- We think we achieve one's own goals by completing supply chain goals
- We think we are conducive to communication with supply chain partners
- We think we facilitate knowledge learning with supply chain partners

5. Supply chain agility [7, 18, 34]
- We think when the market changes, business can adjust production varieties.
- We think when the market changes, business processes can be changed in time
- We think when the market changes, resource allocation can be changed in time
- We think when the market changes, the operation mode can be changed in time
- We think when the market changes, business can perceive threats in the market in a timely manner
- We think when the market changes, business can perceive opportunities in the marketing in a timely manner

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