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Quality Information Disclosure and Blockchain Technology Adoption of Competitive Suppliers on the Third-Party E-Commerce Platform

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Abstract: This study investigates the quality information disclosure and blockchain technology adoption strategies of suppliers on a third-party e-commerce platform. Based on a Stackelberg game model, the impacts of blockchain technology adoption on the quality information disclosure decision and profit of the third-party e-commerce platform and suppliers are explored. The results indicate that whether blockchain adoption benefits suppliers depends on the unit blockchain cost and the reliability of quality information. Counterintuitively, higher information reliability may disadvantage suppliers under certain conditions. With the increase in unit blockchain cost, the incentive of suppliers to adopt blockchain is weakened, and suppliers need to adjust their strategies of quality information disclosure according to the adoption situation and the cost of blockchain. Adopting blockchain technology may be unfavorable to the suppliers but beneficial to the third-party e-commerce platform; the platform can incentivize suppliers to adopt blockchain and achieve a win-win situation. These findings provide some valuable managerial implications for the quality information disclosure decision of suppliers and blockchain adoption in the e-commerce platform supply chain.

Keywords: blockchain; quality information disclosure; third-party e-commerce platform; competitive markets

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1. Introduction

With the development of the Internet and the application of new-generation information technology in manufacturing, third-party e-commerce platforms for manufacturing, such as SAP Business Network [1] and CASICloud.com [2], have developed rapidly and gradually become important intermediaries for manufacturing enterprises. Suppliers disclose sufficient and reliable quality information about their productive services or products on third-party e-commerce platforms for manufacturing, which is conducive to attracting manufacturers to purchase and increasing the transactions on the platform. However, the invisibility of suppliers' production processes weakens the reliability of quality information. Blockchain technology, with features of being irreversible, traceable, and trustworthy, has emerged as a solution for gaining manufacturers' trust [3,4]. According to the statistical data, the market of blockchain-based information traceability solutions in the supply chain was valued at USD 2.2 billion in 2023 and is estimated to reach USD 25.2 billion by 2032 [5]. Hence, some third-party e-commerce platforms for manufacturing have adopted blockchain

technology and provide a blockchain service for suppliers to improve the reliability of quality information. For example, SAP Business Network adopts blockchain technology and provides quality information traceability service. CASICloud.com adopts blockchain technology to provide quality information services for suppliers.

By applying the platform's blockchain service, suppliers can record quality information generated in the production process into the blockchain, which is convenient for manufacturers to trace the quality information, monitor the whole process, and enhance the trust of manufacturers in the reliability of quality information. However, when suppliers adopt blockchain technology, they also need to take certain costs, such as paying a certain blockchain service fee to the platform, as well as collecting, uploading, checking, and updating quality information in the production process, into account. Additionally, suppliers must consider how to obtain competitive advantages in the competitive environment, which will complicate their information disclosure and blockchain service adoption decisions.

At present, some research has analyzed the quality information disclosure strategies of competitive suppliers on third-party e-commerce platforms [6–8]. However, they all consider that the information disclosed by suppliers is reliable and do not consider that customers may distrust quality information. There are also studies that analyze the influence of blockchain on the quality information disclosure strategy of the supply chain [9–11], but they did not consider that in the platform supply chain, the platform can provide blockchain services for suppliers. Different from the existing literature, this study considers that the blockchain service provided by the platform can improve the reliability of quality information, and the pricing decision of the blockchain service will affect the supply chain members' operational decisions and profits.

Focus on a supply chain comprising a third-party e-commerce platform for manufacturing, two competing suppliers, and multiple manufacturers, this study establishes a game model to investigate the suppliers' quality information disclosure strategy and blockchain service adoption strategy and the impacts of blockchain technology adoption on the quality information disclosure decision and profit of supply chain members are explored.

2. Literature Review

This study explores the quality information disclosure and blockchain technology adoption strategy of competitive suppliers on third-party manufacturing platforms. Therefore, this study is related to two streams of literature: quality information disclosure and blockchain adoption in the supply chain.

2.1. Quality Information Disclosure

Quality information disclosure has drawn much attention from scholars. Existing studies have investigated the role of quality information disclosure in supply chain management [12–16] as well as the decision of quality information disclosure in different market environments [6–8,17–23]. Some of them considered the monopoly condition and focused on the supply chain consisting of a manufacturer and a retailer. For example, Guo [17] considered that manufacturers could disclose quality information directly or through retailers, studied the manufacturers' optimal strategy of quality information disclosure, and analyzed the impact of disclosure cost on the disclosure decision. Guan and Chen [18] investigated the interactions between a manufacturer's information acquisition and quality disclosure strategies, and they explored the influence of information disclosure cost and consumers' quality preference on manufacturers' decisions. Feng et al. [19] considered different scenarios in which the manufacturer or the retailer discloses quality information, and they studied the influence of consumer's return rate on the manufacturer's and re-

tailer's quality information disclosure decisions. Additionally, some scholars have explored quality information disclosure strategies under market competition. For example, Guo and Zhao [20] studied the motivation of retailers to disclose quality information to consumers under monopoly and competition scenarios, and they analyzed the influence of competition on retailers' disclosure decisions. Zhao et al. [21] considered two manufacturers with heterogeneous product quality competing in a competitive marketplace and explored the optimal disclosure and pricing strategies for manufacturers. Lan et al. [22] investigated retailers' quality information disclosure strategies in three scenarios: monopoly, simultaneous disclosure, and sequential disclosure by competitive retailers. They analyzed the influence of information value and market competition on the retailer's disclosure decision. Guan and Wang [23] investigated firms' optimal information disclosure strategies in a competitive environment with consumers' elation and disappointment. They explored how market competition and horizontal information sharing influence information disclosure strategies.

With the development of the platform economy, third-party e-commerce platforms gradually became the intermediary where products and services were traded. Therefore, some scholars have begun to study the quality information disclosure of the platform supply chain. For example, Wang [6] studied how a bilateral platform disclosed quality information through the minimum threshold and multiple threshold quality screening mechanisms, and he investigated the influence of platform operating costs and cross-network effects on the equilibrium results. Fan et al. [7] investigated an accommodation-sharing platform's optimal quality information disclosure strategy with consideration of consumer uncertainty, and they examined the impacts of the incumbent hotel and market heterogeneity on the platform's quality disclosure decision. Du et al. [8] considered an online expert service platform in which the expert provides service to a mass of consumers, and they investigated how consumers' two-dimensional heterogeneity and the expert's agency pricing strategy with effort costs affect the platform's information disclosure decision. The above literature studied the quality information disclosure of the supply chain, but it does not consider that customers may not believe the information disclosed is reliable. However, due to the invisibility of suppliers' production process and the virtuality of platform transactions, the reliability of quality information will influence the manufacturers' purchasing behavior. Therefore, this study considers the impact of quality information reliability on the suppliers' quality information disclosure strategy and blockchain service adoption strategy.

2.2. Blockchain Adoption in the Supply Chain Management

As blockchain technology has the features being of immutable, irreversible, traceable, and trustworthy, it has been gradually adopted in supply chain management and has attracted the attention of scholars. Some scholars studied the blockchain application strategy of upstream suppliers/brand-name manufacturers [24–26]. For example, considering that manufacturers can use blockchain technology to signal product authenticity, Pun et al. [24] studied the blockchain adoption strategy of a manufacturer when it faced a deceptive counterfeit. Zhang et al. [25] considered that blockchain can trace products to achieve quality transparency and can also stimulate market demand, and they investigated the blockchain adoption strategy of a high-quality manufacturer. Xu et al. [26] considered that some consumers have a limited knowledge of blockchain, and they studied the blockchain adoption strategy of a manufacturer under different market power structures. Meanwhile, some scholars have discussed the influence of blockchain adoption [27,28] and studied operational strategies of upstream suppliers/brand-name manufacturers, such as pricing [29,30], quality decisions [31,32], channel cooperation [33,34], and information disclosure [35–37] under blockchain adoption, wherein the research on the impact of blockchain adoption

on information disclosure is more related to this study. For instance, Zhou et al. [35] considered a supply chain consisting of a supplier and a retailer, in which the supplier and the retailer can choose to adopt blockchain technology to ensure the reliability of information disclosure, and they analyzed supply members' preferences on blockchain technology. Song et al. [36] considered a duopoly competitive market in which two suppliers compete in information disclosure, and they studied the impact of blockchain on information disclosure and consumer surplus. Li et al. [37] explored the optimal joint decision of information disclosure and ordering in a blockchain-enabled luxury supply chain consisting of a manufacturer and two competing retailers.

With the further development and application of blockchain technology, some e-commerce platforms (such as JD.com and Tmall) have also begun to adopt blockchain technology. Therefore, some scholars began to study the blockchain adoption strategy of the e-commerce platform supply chain [38–40]. For instance, Zhang et al. [38] studied a co-opetitive supply chain in which manufacturers and resellers sell products through the e-commerce platform. Considering that blockchain technology can save consumers time in checking products and improve the reliability of products, they studied the adoption strategy of blockchain technology of the platform. Zhou et al. [39] considered blockchain technology can bring higher preference and trust for products on e-commerce platforms, and they explored the blockchain adoption strategy of a platform in a dual-channel supply chain consisting of a manufacturer and the platform. Xu et al. [40] considered that in two competitive e-commerce platforms with heterogeneous service quality, blockchain technology can improve the service level and network effect of platform services, but it will also lead to privacy concerns for consumers. They studied the blockchain adoption strategies of competitive platforms.

Furthermore, several studies investigated information disclosure strategies of the e-commerce platform supply chain, considering the influence of blockchain adoption. Xu and He [9] considered an e-commerce platform that sells a product to consumers directly with voluntary information disclosure by adopting blockchain technology, and they explored the effects of information disclosure strategies on the platform's pricing and consumers' deliberation decisions. Huang et al. [10] investigated the interaction between the e-commerce platform's decision regarding blockchain adoption and information disclosure strategies under the manufacturer's different cooperative mode selection, and they explored how the interplay influences optimal pricing and information disclosure strategies. Wang et al. [11] investigated the optimal information disclosure and equilibrium blockchain adoption strategy for competing e-commerce platforms, and they analyzed how the consumers' beliefs and blockchain cost affect the equilibrium results. The above research focuses on the impact of blockchain adoption on information disclosure strategies, but they do not consider that blockchain technology is provided as a service by the platform. The decision of third-party e-commerce platforms on blockchain service will influence blockchain service application strategies of suppliers, and these strategies further influence the supply chain members' profitability. Therefore, this study investigates the platform's service pricing strategy and further analyzes its impact on the profit of supply chain members.

3. Problem Description and Model Setting

This paper considers a supply chain consisting of a third-party e-commerce platform (hereafter referred to as "platform"), two competing productive service or product suppliers (hereafter referred to as "suppliers"), and multiple manufacturers. In the platform, manufacturers purchase the productive service or product from suppliers. As the transaction intermediary between suppliers and manufacturers, the platform charges proportional commissions ρ from suppliers. The supplier $i \in \{1, 2\}$ can provide alternative produc-

tive services or products at the unit price p_i, and they can disclose quality information through the platform to show their service capabilities and product quality, such as quality certification and inspection reports. Assuming that the quality information disclosed by suppliers can reflect quality advantages, which is preferable to increasing manufacturers' recognition, thus improving manufacturers' purchasing willingness. The amount of quality information disclosure is denoted by α_i. Similar to Huang et al. [10] and Wang et al. [11], this paper assumes that the market demand increases with the improvement of α_i; that is, the more favorable quality information is disclosed by suppliers, the more likely it is to attract more manufacturers to purchase the productive service or product. Quality information disclosure incurs costs for suppliers, such as quality certification, quality testing, and other inputs. Referring to Li et al. [37] and Zhou et al. [39], this paper employs a quadratic form denoted as $\alpha_i^2/2$ to account for the cost of quality information disclosure. Due to the invisibility of suppliers' production process, it is difficult for manufacturers to judge the reliability of quality information disclosed by suppliers, thus weakening their trust in suppliers. This paper assumes that η represents the reliability of the quality information, $\eta \in [0,1]$. To improve suppliers' quality information reliability, the platform adopts blockchain technology and provides blockchain service for suppliers. Suppliers can choose whether to apply the blockchain service provided by the platform. When a supplier applies blockchain service, he can ensure the reliability of quality information, so $\eta = 1$ for this supplier in this condition, and the manufacturer completely trusts the quality information disclosed by this supplier. The platform adopting blockchain technology needs to bear fixed costs f, such as the construction and deployment of blockchain infrastructure and system maintenance. The platform charges the blockchain service fee b. If a supplier applies to the blockchain service, he needs to pay the service fee and bear the unit cost c of quality information collection, uploading, checking, and updating for blockchain adoption. For the convenience of analysis and without loss of generality, this paper standardizes the potential market demand of suppliers to 1.

According to the adoption of blockchain technology by two suppliers, three situations are considered in this paper: neither supplier adopts blockchain technology (NN), only one supplier adopts blockchain technology (BN), and both suppliers adopt blockchain technology (BB). Considering whether a supplier applies blockchain service, the corresponding demand functions can be expressed as:

$$D_i^{NN} = 1 - p_i + \beta p_j + \eta(\alpha_i - \gamma\alpha_j),\ i \in \{1,\ 2\};\ j = 3 - i \tag{1}$$

$$D_i^{BN} = 1 - p_i + \beta p_j + \alpha_i - \eta\gamma\alpha_j \tag{2}$$

$$D_j^{BN} = 1 - p_j + \beta p_i + \eta\alpha_j - \gamma\alpha_i \tag{3}$$

$$D_i^{BB} = 1 - p_i + \beta p_j + \alpha_i - \gamma\alpha_j,\ i \in \{1,\ 2\};\ j = 3 - i \tag{4}$$

where β is the cross-price sensitivity, γ is the cross-information sensitivity. BN represents the scenario in which the supplier i applies the blockchain service and the supplier j does not.

Table 1 summarizes the notations utilized throughout this paper.

Table 1. Model notations and definition.

Notations	Definition
α	The amount of quality information disclosure
p	The productive service or product price of the supplier
γ	Cross-information sensitivity
β	Cross-price sensitivity
η	Reliability of the quality information
ρ	Platform's proportional commissions
b	Platform's blockchain service fee
c	Unit blockchain cost for the supplier
f	Fixed blockchain cost for the platform
D	Market demand for the productive service or product
π	Profit of supply chain members
Subscripts	
i	The supplier on the e-commerce platforms for manufacturing
P	The e-commerce platforms for manufacturing
Superscripts	
NN	Neither supplier applies blockchain service
BN	One supplier applies blockchain service
BB	Both suppliers apply blockchain service

4. Decisions Under Different Blockchain Adoption Strategies

4.1. Neither Supplier Applies Blockchain Service (Scenario NN)

In this scenario, neither of the suppliers applies blockchain service. The optimization problems of each supplier and platform are as follows:

$$\max \pi_i^{NN}(p_i,\ \alpha_i) = (1-\rho)p_i D_i^{NN} - \alpha_i^2/2 \tag{5}$$

$$\max \pi_P^{NN}(\rho) = \sum_{i=1}^{2} \rho p_i D_i^{NN} - f \tag{6}$$

By calculating the Hessian matrix of π_i^{NN} about p_i and α_i, we can know that the Hessian matrix H(p_i,α_i) is negative definite, so π_i^{NN} is strictly jointly concave in p_i and α_i. Let $\partial \pi_i^{NN}/\partial p_i = 0$ and $\partial \pi_i^{NN}/\partial \alpha_i = 0$, the optimal decision of p_i^{NN*} and α_i^{NN*} can be derived, and the equilibrium profits of the two suppliers and platform are obtained. Proof of the main conclusions is provided in the Appendix A. The equilibrium outcomes are shown in Theorem 1.

Theorem 1. *When neither of the suppliers apply blockchain service, the equilibrium outcomes are as follows:*

(1) *The equilibrium decisions of suppliers are:*

$$\alpha_i^{NN*} = \alpha_j^{NN*} = \frac{\eta(1-\rho)}{2-\beta-(1-\rho)(1-\gamma)\eta^2}$$

$$p_i^{NN*} = p_j^{NN*} = \frac{1}{2-\beta-(1-\rho)(1-\gamma)\eta^2}$$

(2) *The equilibrium profits of suppliers and the platform are:*

$$\pi_i^{NN*} = \pi_j^{NN*} = \frac{\left(2-(1-\rho)\eta^2\right)(1-\rho)}{2(2-\beta-(1-\rho)(1-\gamma)\eta^2)^2}$$

$$\pi_P^{NN*} = \frac{2\rho}{\left(2-\beta-(1-\rho)(1-\gamma)\eta^2\right)^2} - f$$

From Theorem 1, the influence of the reliability of the quality information on equilibrium decisions can be obtained, as Corollary 1 shows:

Corollary 1. *When neither of the suppliers applies blockchain service:*

(1) $\partial\alpha_i^{NN*}/\partial\eta > 0$; $\partial p_i^{NN*}/\partial\eta > 0$; $\partial D_i^{NN*}/\partial\eta > 0$;

(2) $\partial\pi_P^{NN*}/\partial\eta > 0$. *There exists a threshold on* $\eta_1 = \frac{2+\beta-4\gamma}{(1-\rho)(1-\gamma)}$, *when* $\eta^2 < \eta_1$, $\partial\pi_i^{NN*}/\partial\eta > 0$; *otherwise,* $\partial\pi_i^{NN*}/\partial\eta < 0$.

Corollary 1 indicates that with the improvement of the reliability of quality information, the manufacturers' demand will increase, and suppliers can raise the price to earn more profits. As a result, the platform can earn more profits.

However, higher reliability of quality information is not always beneficial to suppliers. When the reliability of quality information is below a certain threshold, the profit of suppliers will increase. This is because, with the improvement of the reliability of quality information, suppliers will disclose more quality information. When the reliability of quality information is low, improving quality information reliability and more quality information can effectively stimulate demand. At this time, the profit increment brought by the increase in demand can cover the cost brought by information disclosure, so the profit of suppliers will increase. However, when the reliability of quality information exceeds the threshold, the profit increment brought by the higher demand is difficult to offset the rising cost of quality information disclosure, so the profit of suppliers will be reduced.

4.2. One Supplier Applies Blockchain Service (Scenario BN)

In this scenario, one supplier applies blockchain service to improve the reliability of quality information, while the other supplier does not apply this service. Without a loss of generality, this study assumes supplier i applies blockchain service, and supplier j $(j = 3 - i)$ does not. The platform plays a Stackelberg game with two suppliers. The platform first determines the blockchain service fees, then two suppliers determine price p_i and p_j, and the amount of quality information disclosure α_i and α_j. The optimization problems of each supplier and platform are as follows:

$$\max\pi_i^{BN}(p_i,\ \alpha_i) = ((1-\rho)p_i - b - c)D_i^{BN} - \alpha_i^2/2 \tag{7}$$

$$\max\pi_j^{BN}(p_j,\ \alpha_j) = (1-\rho)p_j D_j^{BN} - \alpha_j^2/2 \tag{8}$$

$$\max\pi_P^{BN}(\rho) = (\rho p_i + b)D_i^{BN} + \rho p_j D_j^{BN} - f \tag{9}$$

Using backward induction to solve the above optimization problems, for given the blockchain service fee b, by calculating the Hessian matrix of π_i^{BN} about p_i and α_i, we can know that the Hessian matrix $\mathrm{H}(p_i, \alpha_i)$ is negative definite, so π_i^{BN} is strictly jointly concave in p_i and α_i. Using the same approach, we can know that π_j^{BN} is strictly jointly concave in p_j and α_j. Solving $\partial\pi_i^{BN}/\partial p_i = 0$, $\partial\pi_i^{BN}/\partial\alpha_i = 0$, $\partial\pi_j^{BN}/\partial p_j = 0$, $\partial\pi_j^{BN}/\partial\alpha_j = 0$, the optimal decision of $p_i^{BN}(b)$, $\alpha_i^{BN}(b)$, $p_j^{BN}(b)$ and $\alpha_j^{BN}(b)$ can be derived.

Anticipating the suppliers' reaction, the platform determines the blockchain service fee b to maximize the profit. Solving $\partial\pi_P^{BN}/\partial b = 0$ can obtain the optimal blockchain service fee b^{BN*}. Substituting b^{BN*} back into $p_i^{BN}(b)$, $\alpha_i^{BN}(b)$, $p_j^{BN}(b)$ and $\alpha_j^{BN}(b)$, the optimal decision of two suppliers can be derived, and the equilibrium profits of the two suppliers and platform are obtained. The equilibrium outcomes are shown in Theorem 2.

Theorem 2. *When one supplier applies blockchain service, the equilibrium outcomes are shown in Table 2.*

Table 2. The equilibrium outcomes of supply chain members under scenario BN.

	Price Decisions	**Information Disclosure Decisions**	**Profits**
Supplier i	$\frac{A_1B_2c-B_5}{2B_1}$	$\frac{(1-\rho)\left(B_2^2c+B_3\right)}{2B_1}$	$\frac{\left(1-\rho^2\right)\left(B_2^2c+B_3\right)^2}{8{B_1}^2}$
Supplier j	$\frac{A_2B_2c+B_4}{2B_1}$	$\frac{(1-\rho)\eta(A_2B_2c+B_4)}{2B_1}$	$\frac{(1-\rho)A_3(A_2B_2c+B_4)^2}{8{B_1}^2}$
Platform	$\frac{A_4c-(1-\rho)B_7}{2B_1}$	Null	$\frac{B_2^2c^2+2B_3c+B_8}{4B_1}-f$

From Theorem 2, the influence of the unit blockchain adoption cost on equilibrium decisions and profits can be obtained, as Corollary 2 shows:

Corollary 2. *When one supplier applies blockchain service:*

(1) *For the supplier who applies blockchain service:* $\partial\alpha_i^{BN*}/\partial c<0$; *there exists a threshold* $\eta_2=\frac{2\rho-\beta\rho\gamma+\beta\gamma}{(1-\rho)(\gamma^2+\rho-\rho\gamma^2)}$, *when* $\eta^2>\eta_2$, $\partial p_i^{BN*}/\partial c<0$, *otherwise,* $\partial p_i^{BN*}/\partial c>0$; $\partial D_i^{BN*}/\partial c<0$; $\partial\pi_i^{BN*}/\partial c<0$;

(2) $\partial\alpha_j^{BN*}/\partial c>0$; $\partial p_j^{BN*}/\partial c>0$; $\partial D_j^{BN*}/\partial c>0$; $\partial\pi_j^{BN*}/\partial c>0$;

(3) $\partial b^{BN*}/\partial c<0$; $\partial\pi_P^{BN*}/\partial c<0$.

Corollary 2(1) indicates that for supplier i, with the increase in unit blockchain cost, they will disclose less quality information to save the cost of information disclosure, but they will not always raise the price. Intuitively, supplier i needs to raise the price with a higher unit blockchain cost to maintain profits. However, when the reliability of quality information is relatively high, supplier i should lower the price. The reason is that blockchain adoption will not bring an obvious advantage when the reliability of quality information is relatively high and there is intense competition in quality information disclosure among suppliers. With the increase in unit blockchain cost, supplier i will disclose less quality information, while supplier j will disclose more quality information to gain a competitive advantage, leading to the loss of demand and the reduction of profits for supplier i. As a result, to make up for the profit loss from increasing unit blockchain cost, supplier i should lower the price for price competition.

From Corollary 2(2), the supplier j that does not apply blockchain will gain more profit with the increase in unit blockchain cost because supplier j has less reliability of quality information, but they do not take the blockchain adoption cost. With the increased unit blockchain cost, supplier i will disclose less quality information. Supplier j can disclose more quality information to attract manufacturers and get more demand, and they can raise the price to make more profits.

As Corollary 2(3) shows, with the increase in the unit blockchain cost, the blockchain technology service fee and profit of the platform are decreased. On the one hand, with the increase in unit blockchain cost, supplier i will disclose less quality information, leading to the loss of demand. Although supplier j can achieve more demand by disclosing more quality information, manufacturers are still concerned about the reliability of supplier j's quality information. The demand increases from supplier j cannot compensate for the demand decreases from supplier i($\partial\left(D_i^{BN*}+D_j^{BN*}\right)/\partial c<0$), so the commission incomes decrease. On the other hand, the demand from supplier i decreases, and the platform needs to lower the blockchain technology service fee to prevent further demand decline, leading

to lower incomes of the blockchain service fee. As a result, the platform will suffer profit loss with the increase in unit blockchain cost.

4.3. Both Suppliers Apply Blockchain Service (Scenario BB)

In this scenario, both suppliers apply blockchain service. The platform plays a Stackelberg game with two suppliers. The platform first decides the blockchain service fee b, and then the supplier decides the price p_i and the amount of quality information disclosure α_i. The optimization problems of each supplier and platform are as follows:

$$\max \pi_i^{BB}(p_i, \alpha_i) = ((1-\rho)p_i - b - c)D_i^{BB} - \alpha_i^2/2 \tag{10}$$

$$\max \pi_P^{BB}(\rho) = \sum_{i=1}^{2} (\rho p_i + b)D_i^{BB} - f \tag{11}$$

Using backward induction to solve the above optimization problems, for given the blockchain service fee b, by calculating the Hessian matrix of π_i^{BB} about p_i and α_i, we can know that the Hessian matrix $\mathrm{H}(p_i, \alpha_i)$ is negative definite, so π_i^{BB} is strictly jointly concave in p_i and α_i. Let $\partial \pi_i^{BB}/\partial p_i = 0$ and $\partial \pi_i^{BB}/\partial \alpha_i = 0$, the optimal decision of $p_i^{BB}(b)$ and $\alpha_i^{BB}(b)$ can be derived.

Anticipating the suppliers' reaction $p_i^{BB}(b)$ and $\alpha_i^{BB}(b)$, the platform determines the blockchain service fee b to maximize the profit. Solving $\partial \pi_P^{BB}/\partial b = 0$ can obtain the optimal blockchain service fee b^{BB*}. Substituting b^{BB*} back into $p_i^{BB}(b)$ and $\alpha_i^{BB}(b)$, the optimal decision of p_i^{NN*} and α_i^{NN*} can be derived, and the equilibrium profits of the two suppliers and platform are obtained. The equilibrium outcomes are shown in Theorem 3.

Theorem 3. *When both suppliers apply blockchain service, the equilibrium outcomes are shown in Table 3.*

Table 3. The equilibrium outcomes of supply chain members under scenario BB.

	Price Decisions	**Information Disclosure Decisions**	**Profits**
Supplier i (Supplier j)	$\frac{A_9}{2(1-\beta)A_5}$	$\frac{(1-\rho)A_8}{2A_5}$	$\frac{A_8^2(1-\rho^2)}{8A_5^2}$
Platform	$\frac{(A_6 c - A_7)}{2(1-\beta)A_4}$	Null	$\frac{A_8^2}{2(1-\beta)A_5} - f$

From Theorem 3, the influence of the unit blockchain adoption cost on equilibrium decisions and profits can be obtained, as Corollary 3 shows:

Corollary 3. *When both of two suppliers apply blockchain service:*

(1) $\partial \alpha_i^{BB*}/\partial c < 0; \partial p_i^{BB*}/\partial c > 0; \partial D_i^{BB*}/\partial c < 0; \partial \pi_i^{BB*}/\partial c < 0;$

(2) $\partial b^{BB*}/\partial c < 0; \partial \pi_P^{BB*}/\partial c < 0.$

Corollary 3 indicates that when both suppliers adopt blockchain technology, the increase in unit blockchain cost is unfavorable to all supply chain members. Specifically, Corollary 3(1) shows that with the increase in unit blockchain cost, suppliers will disclose less quality information and raise the price. Manufacturers need to pay more and get less quality information about the suppliers, leading to decreased demand. As a result, each supplier will suffer a profit loss. The influence of unit blockchain cost on the platform equilibrium is analyzed in Corollary 3(2). The platform should lower the price of blockchain service with the increase in unit blockchain cost. However, less demand from manufacturers

leads to decreased income from the commission and blockchain service. Lowering the price of the blockchain service will further affect the income from the blockchain service. Therefore, the platform's profit decreases with the increase in unit blockchain cost.

From Corollary 1–3, we can compare the profit of suppliers under different scenarios, and this study further observes the blockchain service adoption strategy of suppliers. Profit comparison results of suppliers under different scenarios are concluded in Corollary 4:

Corollary 4. *Profit comparison results of suppliers under different scenarios, as Table 4 shows.*

Table 4. Profit comparison results of suppliers under different scenarios.

Scenarios	Supplier	Conditions	Profit Comparison
Scenario *BN-NN*	Supplier i	$0 < c < c_1$	$\pi_i^{BN*} > \pi_i^{NN*}$
		$c_1 < c < c_{bn}$	$\pi_i^{BN*} < \pi_i^{NN*}$
	Supplier j	$0 < c < c_2$	$\pi_j^{BN*} < \pi_j^{NN*}$
		$c_2 < c < c_{bn}$	$\pi_j^{BN*} > \pi_j^{NN*}$
Scenario *BB-BN*	Supplier i	$0 < c < c_3$	$\pi_i^{BB*} < \pi_i^{BN*}$
		$c_3 < c < c_{bn}$	$\pi_i^{BB*} > \pi_i^{BN*}$
	Supplier j	$0 < c < c_4$	$\pi_j^{BB*} > \pi_j^{BN*}$
		$c_4 < c < c_{bn}$	$\pi_j^{BB*} < \pi_j^{BN*}$

where $c_{bn} = \frac{-B_3}{{B_2}^2}$; $c_1 = c_{bn} + \frac{2B_1\sqrt{(1+\rho)B_{10}}}{{B_2}^2 B_9(1+\rho)}$; $c_2 = \frac{B_4B_9+2B_1}{B_2B_9(\beta\rho-\gamma\rho+\gamma)}$; $c_3 = \frac{B_1-B_{11}B_3}{B_1(1-\beta)+B_{11}{B_2}^2}$; $c_4 = \begin{pmatrix} B_{11}B_1(B_4(1-\beta)-B_2(\beta-1-B_{11}))\sqrt{(1+\rho)B_{10}} \\ -{B_{11}}^2B_2B_4B_{10}(\beta-1-B_{11})+{B_1}^2(1+\rho)(1-\beta) \end{pmatrix} / \begin{pmatrix} {B_1}^2(1+\rho)(1-\beta)^2 \\ +{B_{11}}^2{B_2}^2B_{10}(\beta-1-B_{11}) \end{pmatrix}$; $B_9 = (\rho-1)(\gamma-1)\eta^2+\beta-2$; $B_{10} = 2+(\rho-1)\eta^2$; $B_{11} = -\beta\rho+\rho\gamma-\gamma+\beta-1$.

Corollary 4 indicates that compared with scenario NN, if one supplier (supplier i) applies the blockchain service, he will benefit from the blockchain adoption when the unit blockchain cost is relatively low. Otherwise, supplier i will suffer a profit loss even though he applies the blockchain. The reason is that the blockchain service can improve the reliability of supplier i's quality information, which brings a competitive advantage in quality information disclosure. When the unit blockchain cost is relatively low, supplier i has little cost to obtain more profit. However, with the unit blockchain cost increased, supplier i needs to disclose less quality information to save the cost, and the competitive advantage in quality information disclosure will shrink. Meanwhile, supplier j who does not adopt the blockchain service can disclose more information to alleviate the disadvantage in quality information reliability. As a result, when the unit blockchain cost is relatively high, supplier i suffers a profit loss while supplier j earns more profit. Compared with scenario BN, if supplier j also applies blockchain service, when the unit blockchain cost is relatively low, supplier j will make more profit. In scenario BB, supplier j can improve the reliability of quality information by applying the blockchain service. However, the competition between the two suppliers is fiercer. When the unit blockchain cost is relatively low, the additional profit from blockchain adoption can cover the unit blockchain cost so that supplier j can make more profit from blockchain adoption. At the same time, supplier i loses the competitive advantage in quality information disclosure, so supplier i suffers a profit loss after supplier j applies blockchain service.

5. Blockchain Service Adoption Strategy and Discussion

5.1. Blockchain Service Adoption Strategy

From Corollary 4, the suppliers' decision on blockchain service adoption can be obtained, as Proposition 1 shows.

Proposition 1. *The blockchain service application strategies are as follows:*

(1) *When* $0 < c < \min(c_1, c_4)$, *both suppliers apply blockchain service.*
(2) *When* $\min(c_1, c_4) < c < \max(c_1, c_4)$, *one supplier applies blockchain service.*
(3) *When* $\max(c_1, c_4) < c < c_{bn}$, *neither of the suppliers applies blockchain service.*

To display Proposition 1 more intuitively, we draw Figure 1 to exhibit the blockchain service application strategies.

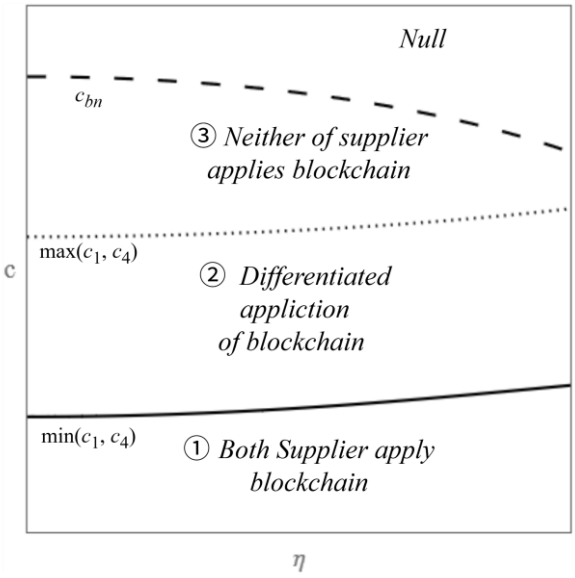


Figure 1. Blockchain service application strategies ($\beta = 0.5$, $\gamma = 0.9$, $\rho = 0.1$).

Proposition 1(1) shows that when the unit blockchain cost is relatively low (Region ① in Figure 1), both suppliers will apply the blockchain service provided by the platform. This is because blockchain adoption can improve the reliability of quality information, and the profit increment is enough to cover the additional cost of blockchain adoption. Therefore, whether the other supplier applies blockchain service or not, the supplier can obtain more profits by applying blockchain service.

However, as Proposition 1(2) shows, if the unit blockchain cost is at a medium level (Region ② in Figure 1), suppliers will choose different service adoption strategies. On the one hand, when one supplier applies to the blockchain service, if the other supplier also applies the blockchain service, it leads to intense competition in quality information disclosure, which will hurt the profits of each supplier. Additionally, the other supplier can make more profit by disclosing more quality information instead of applying the blockchain service. On the other hand, when one supplier decides to ignore the blockchain service, the other supplier can apply the blockchain service to improve the reliability of quality information, and the profit brought by higher information reliability could cover the cost when the unit blockchain cost is not high. Hence, suppliers will choose different service selection strategies.

Proposition 1(3) indicates that both suppliers will not apply the blockchain service when the unit blockchain cost is relatively high (Region ③ in Figure 1). Although blockchain

adoption can improve the reliability of quality information, the additional cost of blockchain adoption is too hard to make up with the income from higher information reliability. As a result, suppliers do not have enough incentives to apply for the blockchain service.

5.2. The Impact of Blockchain Adoption on the Quality Information Disclosure

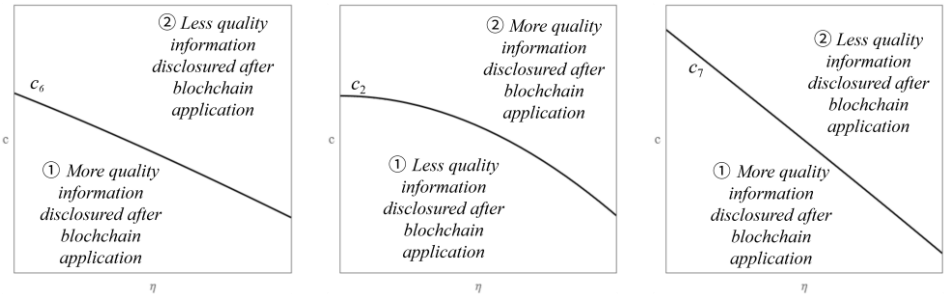
To investigate the impact of blockchain adoption on suppliers' quality information disclosure decisions, this subsection compares the quality information disclosure decisions under different scenarios, as Proposition 2 shows.

Proposition 2. *The impact of the blockchain application on the quality information disclosure decision:*

(1) *Scenario BN- Scenario NN*
For supplier i who apply blockchain service: when $c < c_6$, $\alpha_i^{BN*} > \alpha_i^{NN*}$; *when* $c > c_6$, $\alpha_i^{BN*} < \alpha_i^{NN*}$;
For supplier j who does not apply blockchain service: when $c < c_2$, $\alpha_j^{BN*} < \alpha_j^{NN*}$; *when* $c > c_2$, $\alpha_j^{BN*} > \alpha_j^{NN*}$;

(2) *Scenario BB- Scenario NN*
When $c < c_7$, $\alpha_i^{BB*} > \alpha_i^{NN*}$; *when* $c > c_7$, $\alpha_i^{BB*} < \alpha_i^{NN*}$; *where* $c_6 = c_{bn} + \frac{2\eta B_1}{B_9 B_2^2}$, $c_7 = c_{bb} - \frac{2\eta B_{11}}{B_9(1-\beta)}$.

To display Proposition 2 more intuitively, we draw Figure 2 to exhibit the impact of the blockchain application on quality information disclosure decisions.



(**a**) Quality information disclosure by Supplier i under $BN - NN$

(**b**) Quality information disclosure by Supplier j under $BN - NN$

(**c**) Quality information disclosure by Supplier i under $BB - NN$

Figure 2. The impact of the blockchain adoption on the quality information disclosure decision ($\beta = 0.5$, $\gamma = 0.9$, $\rho = 0.1$).

Proposition 2(1) shows that, compared with scenario NN, when one supplier (supplier i) applies blockchain service, the reliability of supplier i's quality information will be improved. If the unit blockchain cost is relatively low, supplier i can disclose more quality information after adopting blockchain technology (Region ① in Figure 2a) to stimulate demand further. While the reliability of supplier j's quality information is lower than supplier i, supplier j has some disadvantages in quality information disclosure in the market competition, and it is difficult to compete with supplier i by disclosing more quality information to manufacturers. As a result, supplier j will disclose less quality information to save cost ((Region ① in Figure 2b), and supplier i will disclose more quality information with higher reliability to manufacturers. However, if the unit blockchain cost is relatively high, supplier i has to bear the high cost of quality information disclosure after blockchain adoption, and supplier i needs to disclose less quality information to save the cost (Region

② in Figure 2a). As supplier j does not need to pay for blockchain, supplier j can disclose more quality information to obtain a competitive advantage (Region ② in Figure 2b).

Proposition 2(2) indicates that blockchain adoption brings additional costs to the quality information disclosure of each supplier. When the unit blockchain cost is relatively low (Region ① in Figure 2c), each supplier disclosing more quality information after adopting blockchain can stimulate demand significantly with little additional cost. However, when the unit blockchain cost is relatively high (Region ② in Figure 2c), suppliers disclosing more quality information will increase costs. Therefore, after adopting blockchain technology, suppliers need to disclose less quality information to save the information disclosure cost, thus alleviating the profit loss caused by blockchain adoption.

5.3. The Impact of Blockchain Adoption on the Platform

This subsection examines the impact of blockchain adoption on the platform. Comparing the platform's profit under different scenarios, the influence of suppliers' blockchain service application on the platform's profit can be derived, as Proposition 4 shows:

Proposition 3. *The influence of suppliers' blockchain service application on the platform's profit:*

(1) *When* $c < c_8$, $\pi_P^{BN*} > \pi_P^{NN*}$. *When* $c > c_8$, $\pi_P^{BN*} < \pi_P^{NN*}$.

(2) *When* $c < c_9$, $\pi_P^{BB*} > \pi_P^{NN*}$. *When* $c > c_9$, $\pi_P^{BB*} < \pi_P^{NN*}$.

where $c_8 = c_{bn} + \frac{\sqrt{8{B_2}^2 B_1 \rho + \left({B_3}^2 - {B_2}^2 B_8\right) {B_{10}}^2}}{{B_2}^2 B_9}$ *and* $c_9 = c_{bb} + \frac{2\sqrt{\rho(1-\beta)B_{11}}}{B_9(1-\beta)}$.

Proposition 3(1) indicates that, compared with scenario NN, if one supplier (supplier i) applies blockchain service, the platform will benefit from blockchain adoption when the unit blockchain cost is relatively low. With the reliability improvement of supplier i's quality information, the platform can earn more profit through the income from commissions and the blockchain service fee. However, when the unit blockchain cost is high, although the platform can charge for blockchain service, this income cannot compensate for the commission income loss from lower market demand. Similarly, as Proposition 3(2) shows, if both suppliers apply blockchain service, the platform will benefit from blockchain adoption when the unit blockchain cost is relatively low. The profit increment of the platform also includes two aspects: one is the blockchain service fee charged to two suppliers, and the other is the increase in platform transaction volume brought about by the improvement of the reliability of the quality information. When the unit blockchain cost is high, the service fee and the additional income brought by the improvement of the reliability of suppliers' quality information are insufficient to compensate for the profit loss caused by the high blockchain cost. At this time, the platform's profit will be hurt if both suppliers apply blockchain service.

To further investigate the value of blockchain technology adoption for the platform, we consider that the platform does not adopt blockchain technology and does not provide blockchain service for suppliers as a benchmark scenario. When the platform does not adopt blockchain technology (scenario N), the equilibrium decision of each supplier is similar to scenario NN, and the platform does not need to bear fixed costs f such as blockchain technology deployment. According to Theorem 1, when the platform does not adopt blockchain technology, the platform's profit is $\pi_P^{N*} = 2/\left(2 - \beta - (1-\rho)(1-\gamma)\eta^2\right)^2$. When the platform adopts blockchain technology and provides blockchain service for suppliers, the suppliers' blockchain technology adoption strategies are obtained in Proposition 1. By comparing the platform profits under different scenarios, the value of blockchain technology adoption to the platform can be obtained, as shown in Proposition 4.

Proposition 4. *The value of blockchain technology adoption to the platform:*

(1) *When* $0 < c < \min(c_1, c_4)$, *there exists a threshold* f_{bb}, *if* $f < f_{bb}$, $\pi_P^{BB*} > \pi_P^{N*}$; *otherwise*, $\pi_P^{BB*} < \pi_P^{N*}$.

(2) *When* $\min(c_1, c_4) < c < \max(c_1, c_4)$, *there exists a threshold* f_{bn}, *if* $f < f_{bn}$, $\pi_P^{BN*} > \pi_P^{N*}$; *otherwise*, $\pi_P^{BN*} < \pi_P^{N*}$.

(3) *When* $\max(c_1, c_4) < c < c_{bn}$, $\pi_P^{NN*} < \pi_P^{N*}$. *Where* $f_{bb} = \frac{(\beta c - c + 1)^2 {B_{10}}^2 - 4\rho(\beta - 1)B_{11}}{2(\beta - 1){B_{11}}{B_{10}}^2}$ *and* $f_{bn} = \frac{\left({B_2}^2 c^2 + 2B_3 c + B_8\right){B_{10}}^2 - 8\rho B_1}{4B_1 {B_{10}}^2}$.

In Proposition 4, f_{bb} and f_{bn} represent the maximum fixed blockchain cost that the platform can take under scenario BB and BN. It also represents the value that blockchain technology brings to the platform. Proposition 4 (1) and (2) indicate that when unit blockchain cost is relatively low or moderate, the platform cannot gain additional profit through blockchain adoption if the fixed blockchain cost is high. The platform will benefit from adopting blockchain technology when the fixed blockchain cost is relatively low, but with the increase in unit blockchain cost, the value brought by blockchain will decrease ($\partial f_{bb}/\partial c < 0$, $\partial f_{bn}/\partial c < 0$). The reason is that the increase in unit blockchain cost will lead to a decrease in trading volume and profit of the platform (as Corollary 2 and 3 show). From Proposition 1, when the unit blockchain cost is high, both suppliers will not have incentives to apply blockchain service, so the platform cannot gain additional profit through blockchain adoption in this condition.

According to Proposition 1, 3, and 4, when $\max(c_1, c_4) < c < c_8$ and $f < f_{bn}$, both suppliers will not apply the blockchain service from the platform, but blockchain adoption may benefit the platform. If the profit increment of the platform is greater than the profit loss of the supplier after adopting blockchain service, the platform can provide certain transfer payments to the supplier to make the supplier apply blockchain service. In addition, when the unit cost and fixed cost of blockchain are small, blockchain adoption can improve the reliability of quality information disclosed, resulting in a win/win situation for the platform and suppliers.

6. Numerical Analysis

Due to the complexity of the calculation, it is difficult to directly analyze the influence of the reliability of quality information on the equilibrium results under scenario BN. Hence, with the help of mathematical computing software Maple 2019 and MATLAB R2020a, this subsection analyzes the influence of the reliability of quality information on suppliers and platform decisions under scenario BN.

To present the result intuitively, in the range of parameters set in this study, we change the value of the parameter of quality information reliability γ, set $\gamma = 0.2,\ 0.5,\ 0.8$, remain other parameters constant ($\rho = 0.1$, $c = 0.5$, $\beta = 0.5$) and draw Figures 3–5.

By observing Figure 3, with the increase in supplier j's quality information reliability η, when the cross-information sensitivity γ is relatively low, supplier i who applies the blockchain service can charge a higher price and obtain more profit by disclosing more quality information. The reason is that when the competition intensity of information disclosure among suppliers is low, the competitive advantage of blockchain adoption is weaker with the increase in η. Therefore, to maintain competitive advantages, supplier i who applies the blockchain service can disclose more quality information and charge a higher price. However, as Figure 3b,c show, when γ is relatively high, supplier i needs to lower the price and disclose less quality information. Because there is fierce competition in information disclosure, and the increase in information reliability further intensifies the competition, supplier i needs to bear the additional unit blockchain cost and the

cost of quality information disclosure. Disclosing more quality information will further increase costs, so it is difficult for supplier i to compete with supplier j by disclosing more quality information. Supplier i will disclose less quality information to save the cost of information disclosure. Additionally, supplier j disclosing more quality information will lead to supplier i's demand decreasing and higher γ and η will bring more demand loss. As a result, supplier i has to lower the price to alleviate the demand loss.

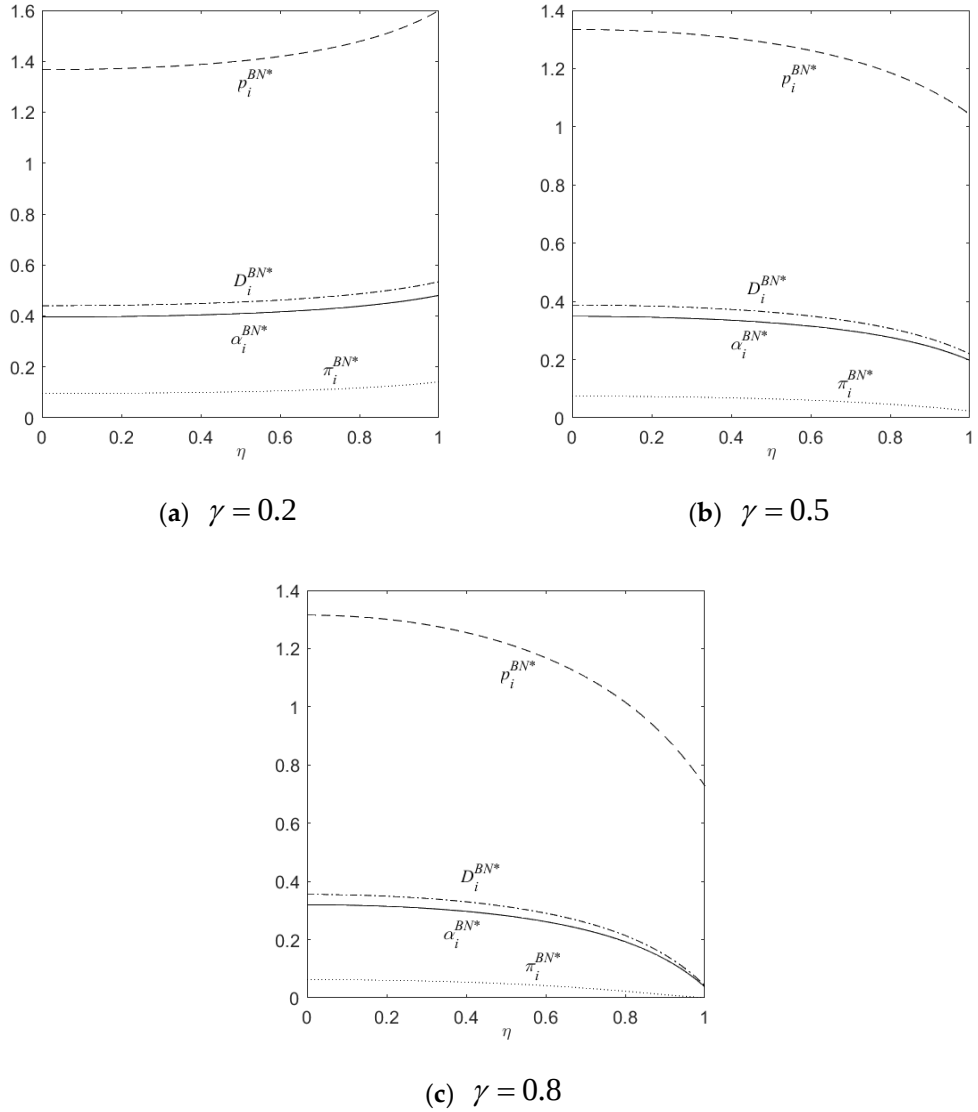


Figure 3. The impact of quality information reliability on decision-making and profit of supplier i ($\rho = 0.1$, $c = 0.5$, $\beta = 0.5$).

Figure 4 illustrates that, for supplier j who does not apply blockchain service, with the reliability improvement of quality information, supplier j can obtain more profit by charging a higher price and disclosing more quality information because supplier j has a disadvantage in the reliability of quality information, but this advantage will shrink with η increasing. Therefore, supplier j can disclose more quality information to attract manufacturers and charge a higher price to obtain more profit.

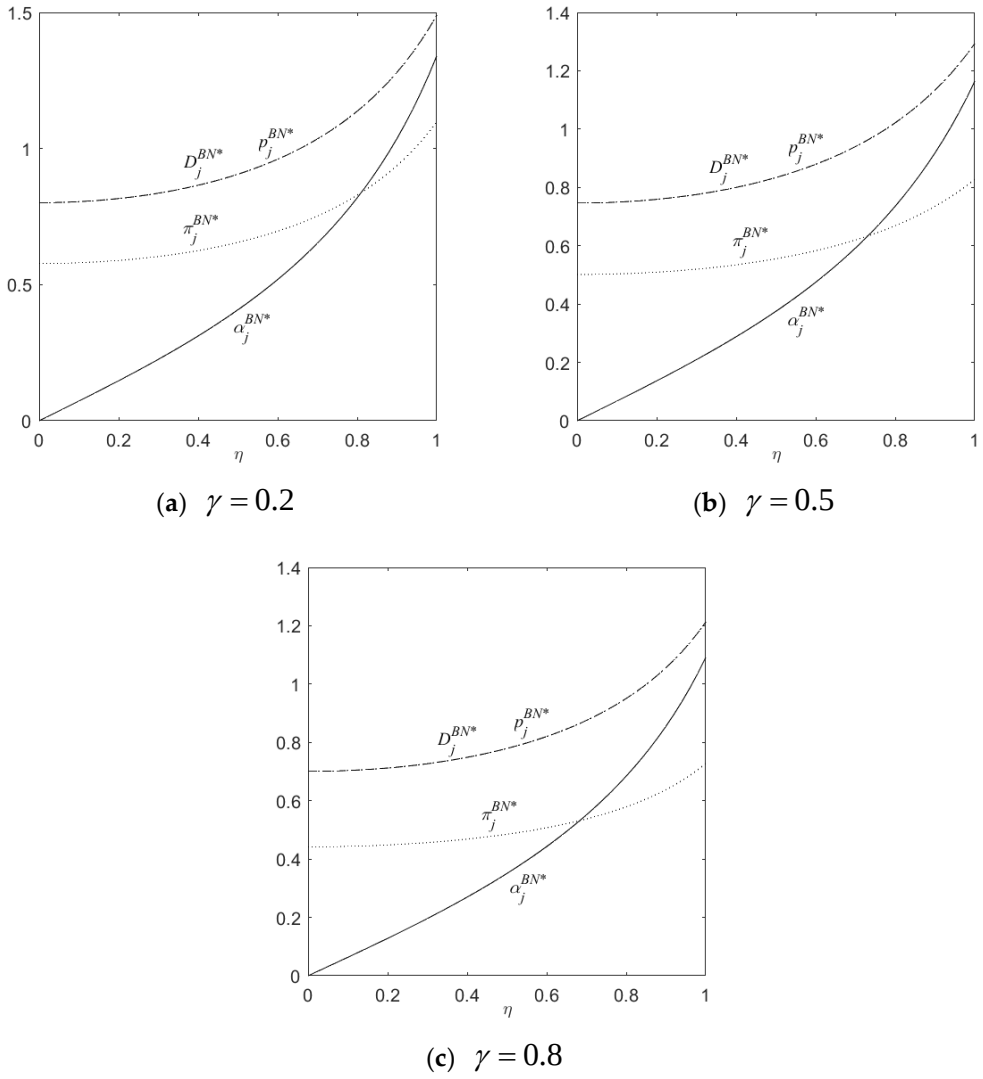


Figure 4. The impact of quality information reliability on decision-making and profit of supplier j ($\rho = 0.1$, $c = 0.5$, $\beta = 0.5$).

Figure 5 indicates that, with the improvement of supplier j's quality information reliability η, the demand increase from supplier j surpasses the demand loss from supplier i, resulting in more platform trading volume. When the cross-information sensitivity γ is relatively low, the platform can charge a higher blockchain service fee and earn more profits. When γ is relatively high and η is lower than the threshold, the platform needs to lower its blockchain service fee, and the additional commission income from higher trading volume cannot compensate for the profit loss from a lower blockchain service fee. As a result, the platform will suffer a profit loss. When γ is relatively high and η is larger than the threshold, the platform also needs to lower its blockchain service fee, but the additional commission income from higher trading volume can cover the profit loss from a lower blockchain service fee so that the platform will earn more profit.

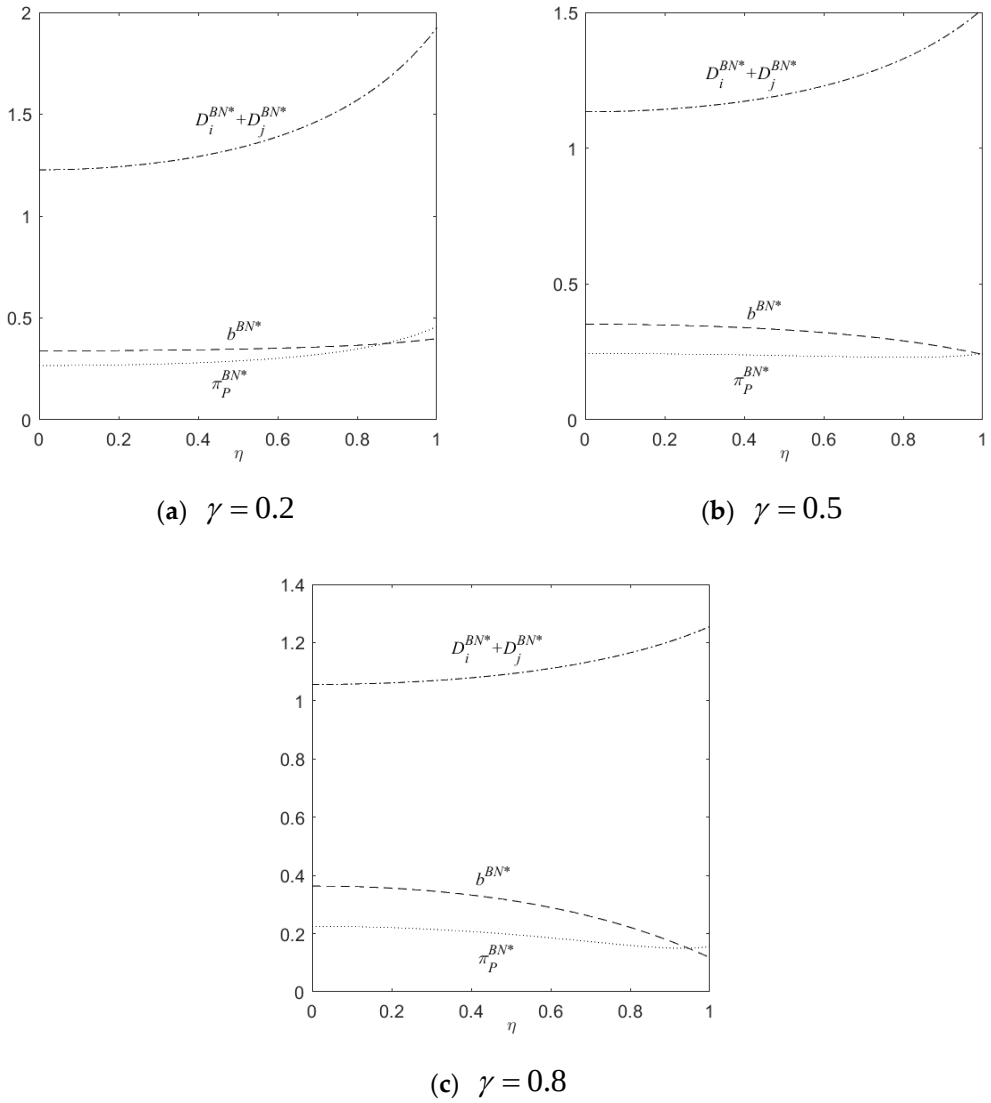


Figure 5. The impact of quality information reliability on decision-making and profit of platform ($\rho = 0.1$, $c = 0.5$, $\beta = 0.5$).

7. Conclusions and Future Directions

7.1. Conclusions

Suppliers disclosing sufficient and reliable quality information about their productive services or products on third-party e-commerce platforms for manufacturing is conducive to attracting manufacturers to purchase. However, the invisibility of suppliers' production processes weakens the reliability of quality information. As an important approach to improving the reliability of quality information and acquiring the trust of manufacturers, third-party e-commerce platforms and suppliers have started to adopt blockchain technology. Therefore, this study focuses on a supply chain comprising a third-party e-commerce platform for manufacturing, two competing suppliers, and multiple manufacturers. Considering that blockchain technology can improve the reliability of quality information, this study establishes a game model to investigate the suppliers' quality information disclosure strategy and blockchain service adoption strategy, and the impact of blockchain technology adoption on suppliers' quality information disclosure decisions is explored. The results indicate that when competitive suppliers make differentiated blockchain adoption strategies, the supplier that adopts blockchain service should disclose more quality information. With the increase in unit blockchain cost, the supplier that does not adopt blockchain service

should disclose more quality information and charge a higher price to cope with market competition. The supplier that adopts blockchain service should disclose less quality information and charge a lower price when the reliability of quality information is high. With the increase in the unit blockchain cost, the blockchain technology adoption strategy shifts from both suppliers adopting to only one adopting, and finally, to no supplier adopting. When the unit cost and fixed cost of blockchain technology are small, the value brought by blockchain technology can achieve a win-win situation for the platform and suppliers.

7.2. Managerial Implications

(1) For competitive suppliers on the platform: Competitive suppliers need to consider both the competition situation of blockchain adoption and the impact of blockchain technology cost to formulate their quality information disclosure strategies. Although the adoption of blockchain technology will bring additional costs, suppliers should disclose more information after adopting blockchain technology when the blockchain cost is low. In addition, when suppliers take differentiated blockchain adoption strategies, the supplier that adopts blockchain needs to disclose more quality information to gain a competitive advantage when the blockchain cost is relatively low. To cope with the market competition, the supplier without blockchain technology should disclose more information with lower disclosure costs when the blockchain cost is relatively high.

(2) For third-party e-commerce platforms: Introducing blockchain technology and providing blockchain technology services to suppliers will expand the revenue source of the platform. However, the platform and suppliers cannot always obtain more benefits by adopting blockchain technology. As a result, the platform needs to adjust its pricing decision for blockchain service according to the blockchain cost. In addition, under certain circumstances, the platform should incentivize suppliers to adopt blockchain services by providing subsidies to suppliers so as to achieve win/win cooperation among supply chain members.

7.3. Limitations and Future Directions

There are several limitations in this study, which could be references for future research. Firstly, this study constructs a Stackelberg game model with a third-party e-commerce platform and two competitive suppliers. However, the market structure is more complex than this fixed market structure. With multi-player Stackelberg models or simulation-based analysis, future research can extend supply chain networks (i.e., more suppliers/platforms or considering government regulations/support) and explore blockchain adoption decisions under more realistic market structures. Secondly, in this study, we assume that supply chain members have full rationality and complete information about manufacturers' preferences. Future research can consider the impact of uncertainty factors such as risk-averse behavior and heterogeneous preferences of manufacturers, and scholars can explore the influence of these factors on blockchain adoption by applying stochastic modeling. Lastly, future research can provide empirical validation of blockchain-related adoption behavior, including the influence of quality information reliability of suppliers and the information sensitivity of manufacturers, which can extend this study and enrich the existing literature.

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Appendix A

Proof of main conclusions

Proof of Corollary 4. As $\pi_i^{BN*} - \pi_i^{NN*} = (1-\rho)\Big((1+\rho)\big(B_2^2 c + B_3\big)^2/8{B_1}^2 - B_{10}/2{B_9}^2\Big)$, the denominator is positive, numerator is a concave function of c, $\Delta > 0$.

By solving $\pi_i^{BN*} - \pi_i^{NN*} = 0$, we can get $c_1 = c_{bn} + 2B_1\sqrt{B_{10}}/B_9 B_2^2\sqrt{1+\rho}$. To make all decisions in scenario BN is meaningful, $c < c_{bn} = -B_3/{B_2}^2$.

As a result, there exist a threshold c_1, $0 < c_1 < c_{bn}$, when $c < c_1$, $\pi_i^{BN*} > \pi_i^{NN*}$; when $c > c_1$, $\pi_i^{BN*} < \pi_i^{NN*}$. As $\pi_i^{BB*} - \pi_i^{BN*} = (1-\rho^2)\Big(\Big((\beta-1)^2\big(c^2+2c\big)+1\Big)/8{B_{11}}^2 - \Big({B_2}^2\big(c^2+2B_3c\big)+{B_3}^2\Big)/8{B_1}^2\Big)$, the denominator is positive, numerator is a concave function of c, $\Delta > 0$. By solving $\pi_i^{BB*} - \pi_i^{BN*} = 0$, we can get $c_3 = (B_1 - B_{11}B_3)/\Big(B_1(1-\beta) + B_{11}{B_2}^2\Big)$.

To make all decisions in scenario BN and BB is meaningful, it needs $c < c_{bn} = -B_3/{B_2}^2$, $c < c_{bb} = 1/(1-\beta)$, and $c_{bn} < c_{bb}$. Therefore, $c < c_{bn}$. As a result, there exist a threshold c_3, $0 < c_3 < c_{bn}$, when $c < c_3$, $\pi_i^{BB*} < \pi_i^{BN*}$; when $c > c_3$, $\pi_i^{BB*} > \pi_i^{BN*}$.□

Proof of Proposition 3. As $\pi_P^{BN*} - \pi_P^{NN*} = \big(B_2^2c^2 + 2B_3c + B_8\big)/4B_1 - 2\rho/{B_9}^2$, the denominator is positive, numerator is a concave function of c, $\Delta > 0$. By solving $\pi_P^{BN*} - \pi_P^{NN*} = 0$, we can obtain $c_8 = c_{bn} + \sqrt{8{B_2}^2B_1\rho + \Big({B_3}^2 - {B_2}^2B_8\Big){B_9}^2}/{B_2}^2B_9$. When $c < c_8$, $\pi_P^{BN*} > \pi_P^{NN*}$; when $c > c_8$, $\pi_P^{BN*} < \pi_P^{NN*}$.

As $\pi_P^{BB*} - \pi_P^{NN*} = \big((\beta-1)c^2 + 2c\big)/2B_{11} - 2\rho/{B_9}^2 + 1/2B_{11}(\beta-1)$, the denominator is positive, numerator is a concave function of c, $\Delta > 0$. By solving $\pi_P^{BB*} - \pi_P^{NN*} = 0$, we can obtain $c_9 = c_{bb} + 2\sqrt{\rho B_{11}}/B_9\sqrt{1-\beta}$. When $c < c_9$, $\pi_P^{BB*} > \pi_P^{NN*}$; when $c > c_9$, $\pi_P^{BB*} < \pi_P^{NN*}$.□

Proof of Proposition 4. When $0 < c < \min(c_1, c_4)$, the equilibrium blockchain adoption result is BB, and $\pi_P^{BB*} - \pi_P^{N*} = \big((\beta-1)c+1\big)^2\big(1-\rho^2\big)/2{B_{11}}^2 - 2B_9/{B_{10}}^2 - f$. To make $\pi_P^{BB*} - \pi_P^{N*} > 0$, we can get $f < f_{bb} = \big((\beta-1)c+1\big)^2\big(1-\rho^2\big)/2{B_{11}}^2 - 2B_9/{B_{10}}^2$, and $\partial f_{bb}/\partial c = \big((\beta-1)c+1\big)/2B_{11} < 0$.

When $\min(c_1, c_4) < c < \max(c_1, c_4)$, the equilibrium blockchain adoption result is BN, $\pi_P^{BN*} - \pi_P^{N*} = \big(B_2^2c^2 + 2B_3c + B_8\big)/4B_1 - 2\rho/{B_{10}}^2 - f$. To make $\pi_P^{BB*} - \pi_P^{N*} > 0$, we can get $f < f_{bn} = \big(B_2^2c^2 + 2B_3c + B_8\big)/4B_1 - 2\rho/{B_{10}}^2$, and $\partial f_{bn}/\partial c = \big(B_2^2c + B_3\big)/2B_1 < 0$.

When $\max(c_1, c_4) < c < c_{bn}$, the equilibrium blockchain adoption result is NN, and $\pi_P^{NN*} - \pi_P^{N*} = -f < 0$.

Where

$A_1 = \big((\rho-1)\big((\rho\gamma^2 - \gamma^2 - \rho)\eta^2 + \beta\lambda\big) - 2\rho\big)$, $A_2 = \gamma\rho - \beta\rho - \gamma$, $A_3 = \rho\eta^2 - \eta^2 + 2$, $A_4 = B_2B_6 + 2\rho A_2^2$, $A_5 = 1 - (\rho-1)(\gamma-\beta)$, $A_6 = (1-\beta)\big(\gamma\rho^2 - \rho^2 - \rho\beta - \gamma + \beta - 1\big)$, $A_7 = (1-\rho)((\gamma+1)(\rho-1) + \beta - 2\beta\rho)$, $A_8 = 1 - (1-\beta)c$

$$B_1 = \Big((\gamma-\beta)(\rho-1)\Big((\rho-1)\eta^2\gamma + \beta\Big) - (\rho-1)\eta^2 - 2\Big)B_2 - \rho(\gamma\rho - \beta\rho - \gamma)^2;$$

$$B_2 = (\beta\gamma - 1)(\rho-1)\eta^2 + \beta^2 - 2;$$

$$B_3 = \Big((\gamma+1)(\rho-1)\eta^2 + \beta + 2\Big)B_2 - 2\rho(\beta+1)(\gamma\rho - \beta\rho - \gamma);$$

$$B_4 = \begin{array}{l}((1-\rho)\eta^2\gamma-\beta)((2\beta+1)(\gamma-\beta)(\rho-1)+\beta)\\ +(2+\rho\eta^2-\eta^2)(2\beta+2+\gamma\rho-\beta\rho-\gamma)\end{array};$$

$$B_5 = \begin{pmatrix} (\rho-1)^2\eta^4(\gamma+1)((\rho-1)(\gamma^2-2\gamma\beta+1)-1)+(\rho-1)\eta^2(2\gamma^2-\beta) \\ +(\rho-1)\eta^2\begin{pmatrix}(\rho-1)((\gamma-1)(2\gamma-1)\beta-2(1+2\gamma)\beta^2)\\ +2(\rho-2)(\gamma^2+\gamma+2)\end{pmatrix} \\ +(\gamma\rho-\beta\rho-\gamma)(2\rho(\gamma\rho+\rho-\gamma)+2\beta+\beta^2)-(\beta^2-2)(\beta+2)(\rho-2)\end{pmatrix};$$

$$B_6 = \left(2+(\rho-1)\eta^2\right)\left(\rho^2+1\right)-(\rho-1)(\gamma\rho-\beta+\gamma)\left((\rho-1)\eta^2\gamma+\beta\right);$$

$$B_7 = \begin{pmatrix} \eta^4(\gamma+1)(\rho-1)^2((\rho-1)(\gamma^2+1)-2\beta\gamma(2\rho-1)) \\ -\eta^2\beta\rho(\rho-1)(2\gamma\beta+\gamma+1) \\ -\eta^2(\rho-1)\begin{pmatrix}2(\rho-1)(\beta^2\gamma-\beta\gamma^2-\gamma^2-\gamma-2)\\ +\beta(2\rho-1)(\gamma+\beta-1)\end{pmatrix} \\ +(\gamma\rho-\beta\rho-\gamma) \\ (2\rho(\gamma\rho+\beta+\rho-\gamma+1)+2\beta+\beta^2)-(\beta^2-2)(\beta+2)(\rho-1)\end{pmatrix};$$

$$B_8 = \begin{pmatrix}(\gamma+1)(\rho-1)\eta^2(2\beta+4+(\gamma+1)(\rho-1)\eta^2)\\ +4\rho(\beta+1)((\gamma-\beta)(\rho-1)+1)+(\beta+2)^2\end{pmatrix}$$

□

References

1. Basu, A.; Bhaskaran, S.; Mukherjee, R. An Analysis of Search and Authentication Strategies for Online Matching Platforms. *Manag. Sci.* **2019**, *65*, 2412–2431. [CrossRef]
2. Li, W.; Zhang, Y.; Dan, B.; Zhang, X.; Sui, R. Simulation Modeling and Analysis on the Value-Added Service of the Third-Party E-Commerce Platform Supporting Multi-Value Chain Collaboration. *J. Theor. Appl. Electron. Commer. Res.* **2024**, *19*, 846–862. [CrossRef]
3. Deloitte. Using Blockchain to Drive Supply Chain Transparency. 2023. Available online: https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html (accessed on 15 May 2025).
4. Li, J.; Wang, X.; Li, L.; Zhao, D. Using Blockchain Technology to Combat Counterfeits: The Optimal Pricing Scheme of Two Competitive Platforms. *J. Theor. Appl. Electron. Commer. Res.* **2024**, *19*, 3253–3282. [CrossRef]
5. Allied Analytics LLP. Blockchain in Supply Chain Traceability Solutions Market Size, Share, Competitive Landscape and Trend Analysis Report, by Component, by Deployment Mode, by Industry Vertical: Global Opportunity Analysis and Industry Forecast, 2024–2032. 2024. Available online: https://www.alliedmarketresearch.com/blockchain-in-supply-chain-traceability-solutions-market-A324170 (accessed on 15 May 2025).
6. Wang, J. Quality Screening and Information Disclosure in Two-Sided Markets. *Econ. Lett.* **2018**, *171*, 183–188. [CrossRef]
7. Fan, X.; Cheng, T.C.E.; Li, G. Opaque or Transparent: Quality Disclosure Strategy for Accommodation-Sharing Platforms. *J. Theor. Appl. Electron. Commer. Res.* **2022**, *17*, 414–438. [CrossRef]
8. Du, S.; Peng, X.; Nie, T.; Zhu, Y. Information Disclosure and Pricing in the Online Expert Service Platform. *J. Oper. Res. Soc.* **2024**, *75*, 1663–1680. [CrossRef]
9. Xu, Q.; He, Y. Optimal Information Disclosure Strategies for a Retail Platform in the Blockchain Technology Era. *Int. J. Prod. Res.* **2023**, *61*, 3781–3792. [CrossRef]
10. Huang, J.; Xu, B.; Yan, X. Selling Mode Choice and Blockchain Adoption in an E-Commerce Platform with Information Disclosure. *Electron. Commer. Res. Appl.* **2023**, *62*, 101331. [CrossRef]
11. Wang, Y.-Y.; Tao, F.; Wang, J. Information Disclosure and Blockchain Technology Adoption Strategy for Competing Platforms. *Inf. Manag.* **2022**, *59*, 103506. [CrossRef]
12. Hong, X.; Zhou, M.; Gong, Y.; Chen, W. Quality Information Disclosure and Advertising Strategy in a Supply Chain. *Int. J. Prod. Res.* **2023**, *61*, 6291–6307. [CrossRef]
13. Sun, F.; Yang, H.; Chen, J.; Wang, F. Disclosure of Quality Preference-Revealing Information in a Supply Chain with Competitive Products. *Ann. Oper. Res.* **2023**, *329*, 689–715. [CrossRef]
14. Tong, Y.; Li, L.; Yang, D.; Jiang, X. Impacts of Online Intermediary's Platform Openness under Asymmetric Quality Information. *Transp. Res. Part E Logist. Transp. Rev.* **2023**, *173*, 103090. [CrossRef]

15. Wang, Z.; Lei, X.; Ran, L.; Ye, S.; Yang, D. Interaction between Channel Characteristics and Quality Disclosure. *Comput. Ind. Eng.* **2023**, *183*, 109451. [CrossRef]
16. Wu, J.; Lu, W.; Ji, X. The Interactions between Upstream Quality Disclosure and Downstream Entry. *Eur. J. Oper. Res.* **2023**, *309*, 545–559. [CrossRef]
17. Guo, L. Quality Disclosure Formats in a Distribution Channel. *Manag. Sci.* **2009**, *55*, 1513–1526. [CrossRef]
18. Guan, X.; Chen, Y.-J. The Interplay between Information Acquisition and Quality Disclosure. *Prod. Oper. Manag.* **2017**, *26*, 389–408. [CrossRef]
19. Feng, Z.; Xiao, T.; Yu, Y.; Robb, D.J. Quality Disclosure Strategy in a Decentralized Supply Chain with Consumer Returns. *Int. Trans. Oper. Res.* **2020**, *27*, 2139–2156. [CrossRef]
20. Guo, L.; Zhao, Y. Voluntary Quality Disclosure and Market Interaction. *Mark. Sci.* **2009**, *28*, 488–501. [CrossRef]
21. Zhao, M.; Dong, C.; Cheng, T.C.E. Quality Disclosure Strategies for Small Business Enterprises in a Competitive Marketplace. *Eur. J. Oper. Res.* **2018**, *270*, 218–229. [CrossRef]
22. Lan, Y.; Peng, J.; Wang, F.; Gao, C. Quality Disclosure with Information Value under Competition. *Int. J. Mach. Learn. & Cyber.* **2018**, *9*, 1489–1503. [CrossRef]
23. Guan, X.; Wang, Y. Quality Disclosure in a Competitive Environment with Consumer's Elation and Disappointment. *Omega* **2022**, *108*, 102586. [CrossRef]
24. Pun, H.; Swaminathan, J.M.; Hou, P. Blockchain Adoption for Combating Deceptive Counterfeits. *Prod. Oper. Manag.* **2021**, *30*, 864–882. [CrossRef]
25. Zhang, Q.; Li, Y.; Hou, P.; Wang, J. Price Signal or Blockchain Technology? Quality Information Disclosure in Dual-Channel Supply Chains. *Eur. J. Oper. Res.* **2024**, *316*, 126–137. [CrossRef]
26. Xu, X.; Chen, J.; Liu, S.; Yu, Y.; Cheng, T.C.E. Should a Manufacturer Adopt Blockchain When Its Competitor Discloses Blockchain-Enabled Product Quality Information? *Int. J. Prod. Res.* 2025; *Online ahead of print*. [CrossRef]
27. Klöckner, M.; Schmidt, C.G.; Wagner, S.M. When Blockchain Creates Shareholder Value: Empirical Evidence from International Firm Announcements. *Prod. Oper. Manag.* **2022**, *31*, 46–64. [CrossRef]
28. Franke, B.; Fritz, Q.G.; Stenzel, A. The (Limited) Power of Blockchain Networks for Information Provision. *Manag. Sci.* **2023**, *70*, 971–990. [CrossRef]
29. Hu, S.; Lu, J.; Jin, Y. Can Price Still Be an Honest Signal of Products' Quality?—A Perspective of Blockchain Adoption. *Comput. Ind. Eng.* **2024**, *189*, 109945. [CrossRef]
30. Tao, F.; Wang, Y.-Y.; Zhu, S.-H. Impact of Blockchain Technology on the Optimal Pricing and Quality Decisions of Platform Supply Chains. *Int. J. Prod. Res.* **2023**, *61*, 3670–3684. [CrossRef]
31. Ji, G.; Zhou, S.; Lai, K.-H.; Tan, K.H.; Kumar, A. Timing of Blockchain Adoption in a Supply Chain with Competing Manufacturers. *Int. J. Prod. Econ.* **2022**, *247*, 108430. [CrossRef]
32. Zhang, Y.; Liu, N. Blockchain Adoption in Serial Logistics Service Chain: Value and Challenge. *Int. J. Prod. Res.* **2023**, *61*, 4374–4401. [CrossRef]
33. Ma, D.; Shao, W.; Zhang, K.; Hu, J. Marketplace, Wholesale or Hybrid: Considering the Role of Blockchain Implementation in Countering Consumer Mistrust. *Electron. Commer. Res.* 2025; *Online ahead of print*. [CrossRef]
34. Li, Z.; Liu, A.; Li, J.; Xiong, J.; Lu, H. Manufacturer Encroachment Strategies and Decision Timing Considering the Product Traceability Preferences under E-Commerce. *Manag. Decis. Econ.* **2023**, *44*, 4041–4067. [CrossRef]
35. Zhou, Z.; Liu, X.; Zhong, F.; Shi, J. Improving the Reliability of the Information Disclosure in Supply Chain Based on Blockchain Technology. *Electron. Commer. Res. Appl.* **2022**, *52*, 101121. [CrossRef]
36. Song, Y.; Liu, J.; Zhang, W.; Li, J. Blockchain's Role in e-Commerce Sellers' Decision-Making on Information Disclosure under Competition. *Ann. Oper. Res.* **2023**, *329*, 1009–1048. [CrossRef]
37. Li, Z.; Xu, X.; Bai, Q.; Chen, C. Optimal Joint Decision of Information Disclosure and Ordering in a Blockchain-Enabled Luxury Supply Chain. *Ann. Oper. Res.* **2023**, *329*, 1263–1314. [CrossRef]
38. Zhang, H.; Lou, Z.; Hou, F. Incentive for Blockchain Technology Adoption in an Online Platform-based Co-opetitive Supply Chain. *Comput. Ind. Eng.* **2024**, *194*, 110323. [CrossRef]
39. Zhou, Y.; Fu, Y.; Wang, K.; Min, J.; Zhang, X. Competition in the Online Platform: Impacts of Blockchain Technology Adoption. *Int. Trans. Oper. Res.* **2024**, *31*, 4105–4127. [CrossRef]
40. Xu, B.; Li, H.; Zhang, X.; Alejandro, T.B. Equilibrium Blockchain Adoption Strategies for Duopolistic Competitive Platforms with Network Effects. *J. Bus. Res.* **2023**, *164*, 113953. [CrossRef]

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