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| RESEARCH ARTICLE

When Should the Platform adopt Blockchain Technology under the Transparency Awareness and Privacy Concerns?

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| ABSTRACT
More and more companies promote their products as sustainable products, but many firms have been exposed to quality and safety issues, which makes consumer question the true quality of the 'sustainable product'. The platform can adopt blockchain technology to attract more consumers by disclosing reliable product information to the consumer, but it will also result in a risk of privacy leakage through registering the blockchain. Hence, we consider a platform-based supply chain that includes a supplier and a platform. We investigate the pricing and information disclosure decision of the platform, then analyze the blockchain adoption strategy of the platform under the consumer's transparency awareness and privacy concern. We find that when the transparency cost is sufficiently low, it is beneficial for the platform to adopt blockchain technology. Interestingly, blockchain adoption is beneficial for the supplier and the whole supply chain but hurts the platform under a certain threshold. Specifically, the platform is more sensitive to the increase in consumers' privacy concerns and transparency costs compared to the retailer. This is because of the cost of information disclosure. Counterintuitively, when transparency awareness is high, the platform will even decrease the retail price as the increasing proportional cost of blockchain technology. Additionally, we find that there exists a 'win-win-win' strategy when transparency awareness is high, and privacy concern is low, in which the application of blockchain technology will benefit the supplier, platform, and consumers.

| KEYWORDS

Blockchain technology, transparency, privacy concern, platform.

| ARTICLE INFORMATION

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1. Introduction

With the increasing environmental awareness of consumers, "organic" and "green" products are popular. With asymmetric information, to gain the favor of consumers and obtain more profits, some companies deceive consumers by exaggerating products and fictitious origins. Consumers are easily misled by advertising due to a lack of professional knowledge(Kopalle and Lehmann 2006).

In recent years, as more and more safety issues and ingredient fraud have been disclosed, it is difficult for some consumers to ensure that the products are qualified. For example, some companies package raw eggs into eco-eggs for higher profits because consumers are more willing to pay higher prices for ecological, organic, nutritious food[1]. Additionally, the global furniture giant Ikea used illegal timber from Ukraine, and one of the world's preeminent forestry certification organizations failed to stop it from happening[2]. Food company Dannon was fined 45 million dollars. Dannon was telling the consumers how activated yoghurt can boost the immune system and regulate the digestive system disingenuously[3]. These exposed issues make consumers wonder if the products they buy are truly "green". Consumers are increasingly wondering how the products are made and what raw materials are used.

Disclosing production quality information to consumers can help solve deceptive advertising significantly, which can increase the transparency of product information so that consumers can judge whether the product meets its standards(Sun et al. 2021). However, without any guarantee, consumers may not fully believe the information disclosed by the company due to the mutable and false information. In recent years, the blockchain has been considered to be a disruptive technology which can make the supply chain more transparent. The blockchain is a shared database and has unique properties, such as transparency, immutability, and traceability, providing a good solution to the pain points in the supply chain(Babich and Hilary 2020).

For example, Walmart has partnered with IBM to implement an alliance chain platform for the food industry, and companies such as Nestle and Dole Food have joined the alliance chain platform(Choi 2019). The blockchain platform provides a transparent supply chain, and consumers can learn the complete history of the product by scanning the QR code on the package. Amazon is currently helping "Chain of Origin", a brand of Nescafe, to develop blockchain technology that can show information about which farm coffee beans are grown, where they are roasted, and when and how they are made(Shen, Dong, and Minner 2021). The information disclosed by the blockchain enhances consumers' trust in the product, thereby promoting their purchase intention.

However, blockchain can only ensure the reliability and transparency of the data after uploading. Therefore, when adopting the blockchain, the firm also needs to invest in some technology to record components' usage history and provenance information (e.g. RFID, sensor, and identifier)(Zhou et al. 2022). So we refer to these technologies recording history and provenance information as transparency technologies when the blockchain is adopted.

Although the blockchain is a good solution to make a transparent and immutable supply chain, we also need to consider the consumer privacy concern brought by blockchain adoption(Pun, Swaminathan, and Hou 2021; Zhou et al. 2022). For example, Chow Tai Fook Jewelry uses blockchain digital verification instead of traditional paper verification, where consumers view the diamond's certification report through an app. When consumers inquire about the history information of the diamond, Chow Tai Fook encourages consumers to register in the app and upload their personal information to the blockchain to indicate their ownership of the purchased products. But this may make some consumers give up buying products with blockchain due to concerns about privacy leakage risks such as price discrimination and security issues.

Recent research shows that more than 90% of consumers are concerned about their online privacy[1]. Customers cannot avoid entering their relevant information when registering and expose to a risk of privacy leakage[2]. As a result, if consumers are very concerned about their private information, the benefit of the blockchain may be reduced. Therefore the platform should weigh the information transparency benefit and the blockchain cost and consumer privacy concerns when deciding whether to adopt blockchain.

In our study, we develop a model with a platform and a supplier. We focus on the following research questions: (1) When should the platform adopt blockchain, and what is the optimal transparency decision of the platform with blockchain? (2) How will the blockchain affect the profit of the supplier, consumer surplus, and social welfare? (3) What is the impact of transparency awareness and privacy concerns on the pricing decision and transparency decision?

1. https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/consumer-data-privacy-and-personalization-at-scale
2. https://www.technologyreview.com/2017/08/23/149531/bitcoin-transactions-arent-as-anonymous-as-everyone-hoped/

To address the above research questions, we consider two scenarios: with blockchain technology (scenario B) or without (scenario N). In scenario B, the platform makes the transparency decision and pricing decision. In scenario N, the platform should make a pricing decision. We compare the equilibrium results through the Stackelberg game between the platform and supplier. Then, we analyze the conditions of when the platform will adopt blockchain and then investigate the condition supplier, platform, consumer, and social welfare can benefit from blockchain adoption.

2. Model settings

Blockchain technology can improve the reliability of product information disclosure, facilitate consumers to verify whether the product is qualified, and improve consumers' understanding of product information. Given this background, we consider a platform-based supply chain that includes a supplier (S, she) and a platform (R, he). We consider that the supplier determines the wholesale price w and the platform determines the retail price p. The platform needs to weigh the advantages of information disclosure brought by blockchain technology against the disadvantages of consumer privacy concerns and investment costs before deciding when to apply blockchain technology. We consider two cases, scenario N, at this time, the platform does not use blockchain technology, scenario B, the platform applies blockchain technology, and the supplier also joins the blockchain system, which improves information transparency.

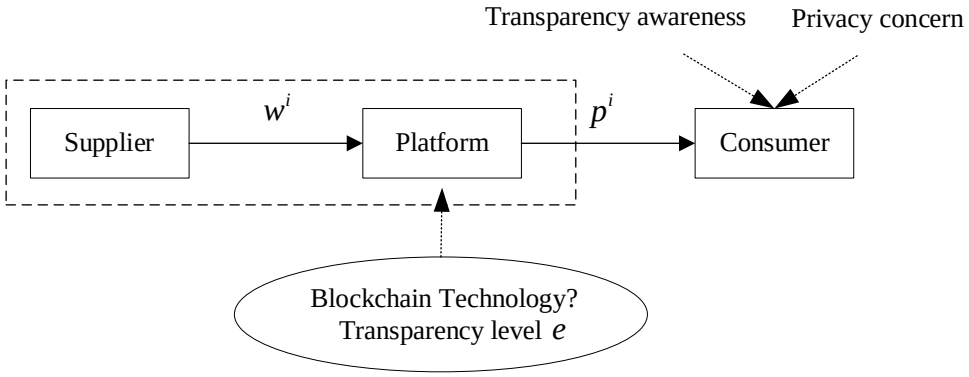

Fig.1. model structure

Following (Niu, Xu, and Chen 2022) and (T. Zhang, Li, and Wang 2021), We use the variable v to represent the consumer's willingness to pay (WTP) for a unit of product. Consumers are heterogeneous, $v \sim U[0,1]$. Therefore, when the platform does not adopt blockchain technology, the consumer utility when consumers purchase product is $U^n = v - p^n$.

Blockchain technology can improve the reliability of quality information disclosure, but blockchain can only ensure the reliability of the data after uploading the blockchain. So the platform should invest in some technologies to ensure the safe upload and reliable transmission of data to prevent data from being tampered with(such as RFID and sensor). We assume that the platform determines that the level of information transparency of investment is e (Zhou et al.2022). When the investment information collection and upload equipment system is more complete and reliable, the higher e is. Consumers can also see a wealth of product information such as product raw materials, production process, logistics and transportation, quality inspection, etc. We assume that the transparency cost paid by the platform is ke^2, where k is the coefficient of the transparency cost。

Although blockchain improves the transparency of product information, consumers will also worry that relevant information will be exposed when registering the blockchain platform, resulting in a risk of privacy leakage. In our contribution, we assume that consumers will have privacy concerns when buying blockchain products θ,$\theta \sim (0,1)$ (Zhang et al.2022). If consumers pay great attention to personal privacy, then the information disclosure advantage of blockchain will be weakened.

The utility when the consumer buys the product with blockchain is $U^b = v - p^b + e\,s - \theta$, where $e\,s$ is the increasing consumer utility after the platform adopts blockchain, s represents the transparency awareness of the consumers, $s \sim (0,1)$, θ is the privacy concern of consumers after blockchain adoption.

Additionally, there may be certain costs for supply chain members to adopt blockchain technology. We assume that the supplier needs to pay the marginal cost c per unit of blockchain product, which includes the cost of labeling, data operation, and the smart contract. We assume the unit production cost of the supplier is c_n without blockchains, and the proportional cost of the supplier with blockchain is $c_b = c_n + c$. Additionally, we standardize the fixed cost of the blockchain system to 0, which is a sunk cost for the platform.

Accordingly, the platform should weigh the advantage of the information disclosure effect and the disadvantages of consumer privacy concerns as well as the blockchain deployment cost. The supplier should determine the wholesale price given the platform's blockchain deployment decision. The sequence of the event can be concluded as follows:

Step 1: P decides whether to deploy blockchain or not.

Step 2: if P decides to adopt blockchain technology, she should determine the transparency level e.

Step 3: S determine the wholesale price of the product $w^i (i \in \{n, b\})$.

Step 4: P determine the retail price of the product p^i, $(i \in \{n, b\})$.

All notations involved in the model are listed in table 1.

Table 1 nations

Notations	Description $i \in \{n, b\}$, $j \in \{s, r, sc\}$
v	random variable, WTP of the consumer for the unit product $v \sim [0,1]$
s	transparency awareness of the consumer, $s \in (0,1)$
θ	privacy concern of the consumers for the blockchain technology, $\theta \in (0,1)$
c_n	The unit production cost of the supplier
c_b	The unit cost of the product with blockchain technology, $c^b = c^n + c$. c is the proportional cost of blockchain technology.
U^i	The utility function of consumers
D^i	The market demand function
Π_j^i	Supply member j's profit in scenario i
cs^i	Consumer surplus of scenario i
sw^i	Social welfare of scenario i
Decision variables	
w^i	The supplier's unit wholesale price
p^i	The retailer's unit retail price
e	Transparency level

3. Equilibrium

3.1 Without blockchain adoption (N)

When the platform adopts blockchain, the consumers will buy the product with blockchain if $U^n > 0$. So the demand for the product is $D^n = 1 - p^n$. The supplier will determine the wholesale price w^n, and the platform will determine the retail price p^n to maximize the profit. The profit functions of the retailer and supplier can be expressed as follows:

$$\Pi_s^n = \left(w^n - c_n\right) D^n \quad (1)$$

$$\Pi_r^n = \left(p^n - w^n\right) D^n \quad (2)$$

Meanwhile, the consumer surplus and social welfare in scenario N can be summarized as follows:

$$cs^n = \int_{p^n}^1 U^n dv \quad (3)$$

$$sw^n = \prod {}_s^n + \prod {}_r^n + cs^n \quad (4)$$

It is easy to find that Π_r^n (Π_s^n) is a concave function, according to the principle of profit maximization, using the inverse solution method to solve Eqs. (1)-(2) the platform's equilibrium retail price p^{n*} and the supplier's optimal wholesale price w^{n*} are found by the first-order condition.

Lemma 1. The equilibrium outcomes without blockchain adoption are shown in table 2.

Table 2 The equilibrium outcomes without blockchain adoption

Platform	Supplier
$p^{n*} = \frac{3 + c_n}{4}$	$w^{n*} = \frac{1 + c_n}{2}$
$D^{n*} = \frac{1 - c_n}{4}$	
$\Pi_R^{n*} = \frac{1}{16}(1 - c_n)^2$	$\Pi_S^{n*} = \frac{1}{8}(1 - c_n)^2$
$\Pi_{sc}^{n*} = \Pi_s^{n*} + \Pi_r^{n*} = \frac{3}{16}(1 - c_n)^2$	
$cs^{n*} = \frac{1}{32}(1 - c_n)^2$	
$sw^* = \frac{7}{32}(-1 + c_n)^2$	

3.2 With blockchain adoption(B)

When the platform adopts blockchain technology, the consumer can obtain more reliable information about the product. According to the consumer utility, we can get that the market demand for the platform $D^b = 1 - p^b + e\,s - \theta$. The platform will first determine the information transparency level e; then, the supplier will determine the wholesale price w^b, and the platform will decide the retail price p^b finally. We require $16k > s^2$ and $c_b < 1 - \theta$ to ensure positive outputs and rule out trivial cases. In other words, the transparency cost is not excessively low, and the proportional blockchain cost can not be too high when the platform adopts blockchain technology. Otherwise, the platform will not adopt blockchain. The profit functions of the platform and supplier with blockchain adoption can be expressed as follows:

$$\Pi_s^b = \left(w^b - c_b\right) D^b \tag{5}$$

$$\Pi_r^b = \left(p^b - w^b\right) D^b - ke^2 \tag{6}$$

Similarly, the consumer surplus and social welfare in scenario B can be summarized as follows:

$$cs^b = \int_{p^b+\theta-e\,s}^{1} U^b dv \tag{7}$$

$$sw^b = \prod {}_s^b + \prod {}_r^b + cs^b \tag{8}$$

It is easy to find that Π_s^b (Π_r^b) is a concave function, according to the principle of profit maximization, using the inverse solution method to solve Eqs. (5)-(6), the platform's equilibrium transparency level e^*, retail price p^{b*} and the supplier's optimal wholesale price w^{n*} is found by the first-order condition.

Lemma 2. The equilibrium outcomes with blockchain adoption are shown in table 3.

Table 3 The equilibrium outcomes with blockchain adoption

Platform	Supplier
$p^{b*} = \frac{c_b s^2 - 4k(3 + c_b - 3\theta)}{-16k + s^2}$	$w^{b*} = \frac{c_b s^2 - 8k(1 + c_b - \theta)}{-16k + s^2}$
$e^* = \frac{s(1 - c_b - \theta)}{16k - s^2}$	
$D^{b*} = \frac{4k(1 - c_b - \theta)}{16k - s^2}$	
$\Pi_r^{b*} = \frac{k(-1 + c_b + \theta)^2}{16k - s^2}$	$\Pi_s^{b*} = \frac{32k^2(-1 + c_b + \theta)^2}{(-16k + s^2)^2}$
$\Pi_{sc}^{b*} = \Pi_s^{b*} + \Pi_r^{b*} = \frac{k(48k - s^2)(-1 + c_b + \theta)^2}{(-16k + s^2)^2}$	
$cs^{b*} = \frac{8k^2(-1 + c_b + \theta)^2}{(-16k + s^2)^2}$	
$sw^{b*} = \frac{k(56k - s^2)(-1 + c_b + \theta)^2}{(-16k + s^2)^2}$	

Proposition1 *The equilibrium retail price, wholesale price, transparency level, and market have the following properties*:

(i) $\partial e^*/\partial s > 0$ and $\partial e^*/\partial \theta < 0$.

(ii) $\partial p^{b*}/c_b > 0$ and $\partial w^{b*}/c_b > 0$ if $s < 2\sqrt{k}$, $\partial p^{b*}/c_b < 0$ and $\partial w^{b*}/c_b < 0$ if $s > 2\sqrt{k}$.

Proposition 1 (i) indicates that the platform's transparency level will increase with the consumers' transparency awareness and decrease with the consumers' privacy concerns.

Proposition 1 (ii) shows that, When consumers' transparency awareness is low, the platform will increase the retail price as the proportional cost of blockchain technology increases. Counterintuitively, when transparency awareness is high, the platform will even decrease the retail price as the increasing proportional cost of blockchain technology.

The underlying reason is that when blockchain technology's proportional cost increases, the transparency level of the platform decreases. When the transparency awareness of consumers is small, consumers have a weak perception of the information disclosure utility of blockchain technology, so the platform increases the retail price, and the supplier increases the wholesale price to balance the increasing pressure from the cost of blockchain technology.

However, when consumers' transparency awareness is high, consumers have a strong perception of the information disclosure utility of blockchain technology, consumers will be more willing to buy products based on blockchain technology, and the platform will reduce retail prices to stimulate more consumers to buy and expand the market demand for products.

4 Equilibrium comparison

Before investigating how blockchain adoption affects supply chain profits, we first compare the wholesale price, retail price, and demand without and with blockchain adoption. We have proposition 2.

Proposition2 *the impact on wholesale price, retail price, and demand*

(i) if $\theta < \theta_1$, then $w^{b^*} > w^{n^*}$, where $\theta_1 = c_b - c_n + \frac{(1-2c_b+c_n)s^2}{16k}$

(ii) if $\theta < \theta_2$, then $p^{b^*} > p^{n^*}$, where $\theta_2 = \frac{c_b-c_n}{3} + \frac{(3-4c_b+c_n)s^2}{48k}$

(iii) if $\theta < \theta_3$, then $D^{b^*} > D^{n^*}$, where $\theta_3 = c_n - c_b - \frac{s^2(-1+c_n)}{16k}$; and $\theta_3 < \theta_2 < \theta_1$;

We find that platform is willing to determine a higher wholesale price, and the platform is willing to determine a higher retail price for the product with blockchain when consumer privacy concern is low. This is because, with low consumer privacy concerns, the platform will determine a higher information transparency level, and the blockchain adoption cost will be higher; as a result, the platform increases the retail price to balance the upward pressure on costs.

From proposition 2(ii), we found that the platform transfers the increased blockchain cost to the customers by charging a higher retail price for the blockchain product. When consumer privacy concern is low, the adoption of blockchain for the supplier is costly, so he has to be compensated by the increased wholesale price. The information disclosure effect of blockchain technology will enhance consumers' knowledge of product information and attract more consumers to buy blockchain products, so the demand will increase.

We can show that $\theta_3 < \theta_2 < \theta_1$, which indicates that demand is most sensitive to consumer privacy concerns; changes in consumer privacy concerns have a greater impact on the platform's retail price decision than the supplier's wholesale price decision. We know that when consumer privacy concerns meet a certain threshold (i.e. $\theta_3 < \theta < \theta_2$), the application of blockchain technology will increase the retail price of the platform and the wholesale price of the supplier, but it will decrease consumer demand. This shows that the platform needs to pay attention to consumer privacy concerns when determining retail prices with blockchain.

However, proposition 2 also shows an interesting result that the wholesale price, retail price, and demand can be decreased with blockchain technology adoption when the consumer privacy concern is high. The underlying reasons are as follows. When consumer privacy concern is high, the platform reduces the information transparency level; consumers have insufficient motivation to buy products with blockchain. The advantage of information disclosure will be less than the negative effect brought by consumer privacy concerns when with blockchain. As a result, the platform and supplier will decrease the retail prices and wholesale prices at the same time; consumer demand will also decrease.

See Fig. 2 ($c_n = 0.08, c_b = 0.1, s = 0.4, k = 0.1$)for the illustration. We observe that if the consumer privacy concerns are sufficiently low(i.e.,$\theta < \theta_3$), the application of blockchain technology will simultaneously increase retail prices and wholesale prices. Also, consumer demand will be high with blockchain than without blockchain.

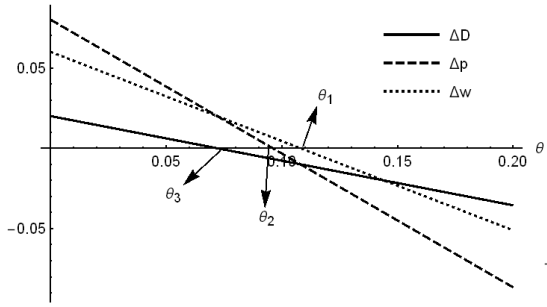

Fig.2. the impact of θ on the comparison of the retail price, wholesale price, and demand

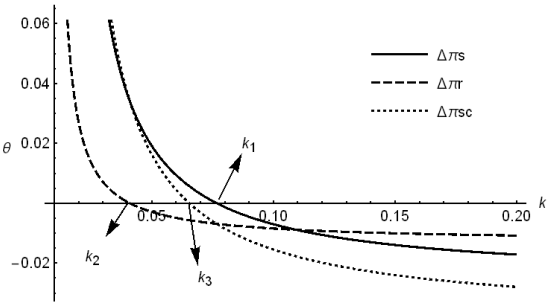

Fig.3. the impact of k on the revenue of supplier, platform, and supply chain

Proposition 3 *supply chain members' preference on blockchain technology*

(i) If $k < k_1$, then $\Pi_s^{b^*} > \Pi_s^{n^*}$, where $k_1 = -\frac{s^2(-1+c_n)}{16(\theta+c_b-c_n)}$;

(ii) If $k < k_2$, then $\Pi_r^{b^*} > \Pi_r^{n^*}$, where $k_2 = -\frac{s^2(-1+c_n)^2}{16(\theta+c_b-c_n)(-2+\theta+c_b+c_n)}$;

(iii) If $k < k_3$, then $\Pi_{sc}^{b^*} > \Pi_{sc}^{n^*}$, where $k_3 = \frac{s^2(-5+(-2+\theta)\theta+c_b(-2+2\theta+c_b)-6(-2+c_n)c_n)-\sqrt{s^4(-1+\theta+c_b)^2(25+(-2+\theta)\theta+c_b(-2+2\theta+c_b)+24(-2+c_n)c_n)}}{96(\theta+c_b-c_n)(-2+\theta+c_b+c_n)}$, and $k_2 < k_3 < k_1$

By comparing the profits of supply chain members with and without blockchain technology, we can know the conditions when should the platform to adopt blockchain technology and analyze the impact of blockchain technology on the supplier and the whole supply chain.

We found that when the transparency cost is sufficiently low (i.e. $k < k_2$) is beneficial for the platform to adopt blockchain technology. Simultaneously, it will also increase the profit of the supplier. It means that blockchain technology is a win-win strategy for both the platform and supplier when the transparency cost is sufficiently low. This indicates that when the platform considers whether to adopt blockchain technology, she should weigh the advantages of quality information disclosure between the cost of transparency.

We also compared the supply chain profits with and without blockchain technology. We found that when the transparency cost is low (i.e. $k < k_3$), the application of blockchain technology will increase the profits of the whole supply chain. At this time, blockchain technology provides consumers with more reliable product information, consumers' demand for blockchain products increases, and the platform will also set higher retail prices, so for the supply chain, the advantages of blockchain technology information disclosure will be greater than the cost.

See Fig. 3($c_n = 0.08, c_b = 0.1, \theta = 0.1, s = 0.4$) for an illustration. We found that if the transparency cost meets a certain threshold(i.e. $k_2 < k < k_3$), blockchain adoption is beneficial for the supplier but hurts the platform. Interestingly, it will benefit the whole supply chain too. It means that the platform is more sensitive to the transparency cost when the platform is willing to adopt blockchain(i.e. $k < k_2$), is always beneficial for the supplier and the whole supply chain.

Proposition 4 *the impact of blockchain technology on the consumer surplus and social welfare*.

(i) If $k < k_1$, then $cs^{b^*} > cs^{n^*}$;

(ii) If $c_n > \frac{1}{3}(11-4\sqrt{7})$, or $c_n < \frac{1}{3}(11-4\sqrt{7})$, $c_b < c_{b1}$ and $\theta < \theta_4$, then $sw^{b^*} > sw^{n^*}$; if $c_n < \frac{1}{3}(11-4\sqrt{7})$ and $c_b > c_{b1}$, or $c_n < \frac{1}{3}(11-4\sqrt{7})$, $c_b < c_{b1}$ and $\theta > \theta_4$, then $sw^{b^*} < sw^{n^*}$; Where $c_{b1} = \frac{448k^2-8ks^2+\sqrt{2}\sqrt{k(16k-s^2)^2(56k-s^2)(3-22c_n+3c_n^2)}}{448k^2-8ks^2}$ and $\theta_4 = \frac{8k(-56k+s^2)(-1+c_b)-\sqrt{2}\sqrt{k(56k-s^2)(-16k+s^2)^2(3+c_n(-22+3c_n))}}{8k(56k-s^2)}$;

We also analyzed the impact of blockchain technology application on consumer surplus and social welfare by comparing the consumer surplus and social welfare before and after the application of blockchain technology in proposition 4(i). We found that when transparency cost is less than a threshold (i.e. $k < k_1$), the consumer surplus will be higher when the platform adopts blockchain than without blockchain.

The underlying reasons are as follows: if the transparency cost is low, the platform's transparency level of the blockchain product is high (*e* is high enough), the consumer will know more about the product. Although the retail price is higher with blockchain compared with the no-blockchain product, the advantage effect of quality information disclosure with blockchain is higher than the disadvantage of increasing retail price cost for the consumers.

By comparing social welfare with and without blockchain, we found that whether the blockchain is beneficial for social welfare is relatively corresponding to the production cost, blockchain proportional cost, and consumer privacy concern. Specifically, as proposition 4(ii) shows, when the production cost is higher, or the production cost, proportional blockchain cost, and consumer privacy concern is low, blockchain technology will benefit social welfare. However, when the production cost is low, and the proportional blockchain cost is high, or both the production cost and proportional blockchain cost are low, and consumer privacy concern is high, social welfare will decrease with blockchain compared to without blockchain.

The above conclusion provides some management insights well. When the production cost is high, it means that the product value is high, consumers want to know more authenticity information, and they pay more attention to the production, raw materials, and quality, and are always willing to pay a higher price for the product. Our findings reflect reality well. In practice, such as jewelry, diamonds, and those products with a higher value are adopted with blockchain technology.

When the production cost is low, it means that the product value is low(such as clothes, meat, milk, and so on). But when both the proportional blockchain cost and consumer privacy concerns are low, the platform will adopt blockchain as well. The reason is that when the blockchain cost is low both for the supplier and platform, the transparency of the product with blockchain is sufficiently high, but the retail price is not high, the advantage of the blockchain(i.e. information disclosure) will be higher than the disadvantages(i.e. increased cost and consumer privacy concerns). This reflects reality well. With the decreasing cost of blockchain technology, there will be more products with blockchain(such as fruits, clothing, meat, and so on). Meanwhile, blockchain technology is beneficial not only to consumers but also the society.

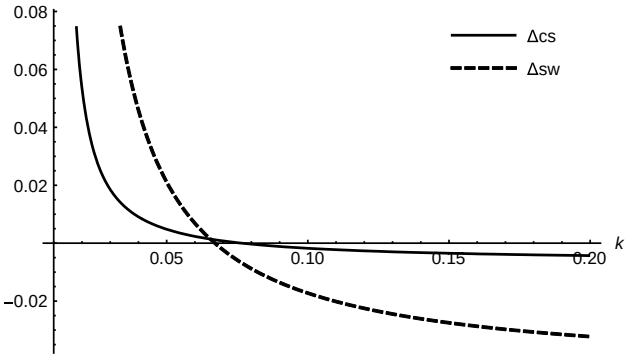

Fig.4. the impact of transparency cost on the comparison of consumer surplus and social welfare($c_n = 0.08, c_b = 0.1, \theta = 0.1, s = 0.4$)

See Fig. 4 for an illustration. We found that social welfare is more sensitive to the transparency cost. This is because the platform and supplier are more sensitive to the increasing transparency cost compared to the consumers. The platform and supplier should bear more cost pressure for the blockchain technology products.

5 Numerical study

In section 4, we focus on the impact of transparency costs on the platform, retailer, and supply chain profits. In this section, we will explore the impact of transparency awareness and privacy concerns on profit comparison through numerical analysis.

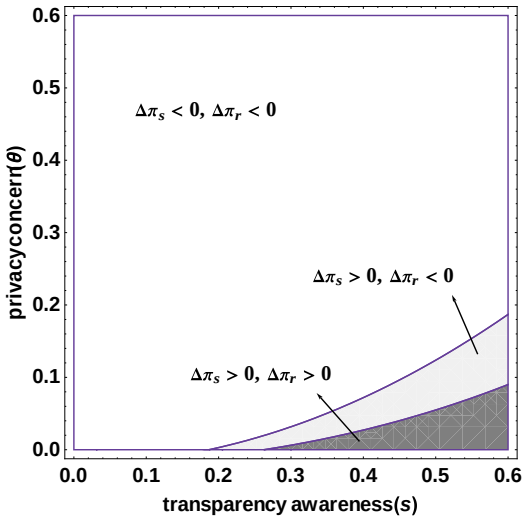

Fig.5. the impact of s and θ on the profit comparison of the platform and supplier

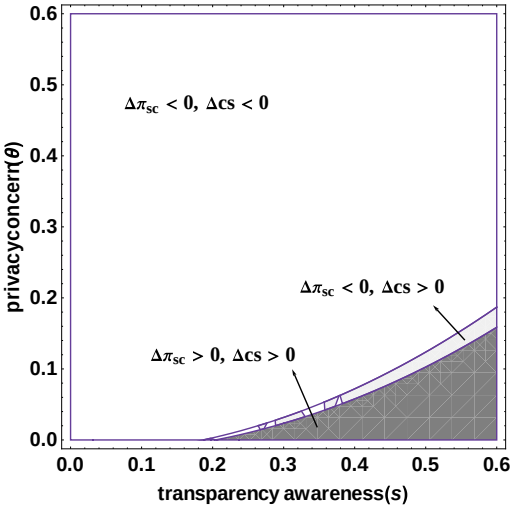

Fig.6. the impact of s and θ on the supply chain profit and consumer surplus

Firstly, we analyze the impact of transparency awareness and privacy concerns on blockchain adoption. We find that when the consumer's transparency awareness is high and privacy concern is low, blockchain adoption will benefit both the platform and suppliers, achieving a win-win situation (gray area in Fig.5). However, with the consumers' privacy concern increasing, the platform's profit will decrease, but blockchain adoption is beneficial to suppliers (light gray area in Fig.5). Meanwhile, when transparency awareness is low, and privacy concern is high, the application of blockchain technology will be unfavorable to the platform and the supplier. Therefore, platforms should pay attention to not only transparency cost but also transparency awareness and privacy concerns of consumers when applying blockchain technology.

Comparing the profits of platforms and suppliers, we find that platform is more sensitive to the increase in consumers' privacy concerns. This is because the platform bears the cost of information disclosure. When consumers buy blockchain technology products, if they are very worried that blockchain technology will leak their private information, then the advantages of blockchain information disclosure will be weakened. So fewer consumers will choose to buy blockchain products compared with the supplier, and the profit of the platform will decline more obviously.

We also investigate whether blockchain technology benefits both supply chain revenue and consumers. Interestingly, we find that when transparency awareness is high, and privacy is low, blockchain technology will increase supply chain revenue and consumer surplus. However, when the privacy concern increases, blockchain technology will harm supply chain revenue but still benefit consumers. This indicates that although consumer privacy concerns will reduce consumers' willingness to purchase blockchain technology products, the information disclosure effect of blockchain technology will significantly enhance consumer surplus compared to no blockchain technology. But the elevated consumer privacy concern will make the supply chain members' gain lower due to the higher blockchain technology cost.

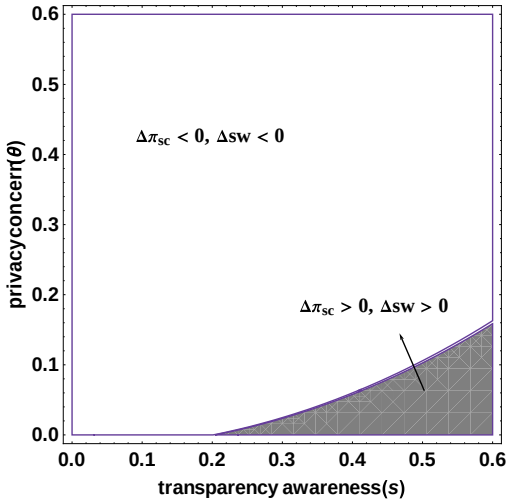

Fig.7. the impact of s and θ on supply chain profit and social welfare

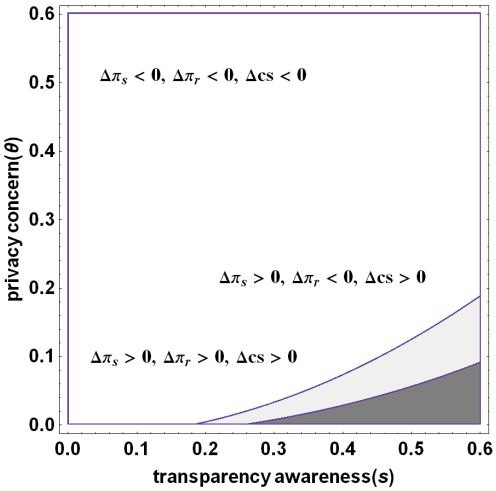

Fig.8. the impact of s and θ on revenue of supplier, platform, and consumer

In addition, we also explore whether blockchain technology is beneficial to both supply chain profit and social welfare. We find that when transparency awareness and privacy are small, blockchain technology will enhance supply chain profit and social welfare. However, when transparency awareness and privacy are large, the application of blockchain technology will harm supply chain profit and also reduce social welfare.

Finally, we also analyze the impact of blockchain technology on the supplier, platform, and consumers. Interestingly, we find that there exists a 'win-win-win' strategy under certain conditions. Specifically, when transparency awareness is high, and privacy concern is low (dark gray area in Fig.8), the application of blockchain technology will benefit the supplier, platform, and consumers. But when the consumer privacy concern increases, the application of blockchain technology will harm the platform revenue(gray area in Fig.8). Reason underlying this is that the information disclosure advantage of blockchain technology will be less than the cost of information disclosure. So the platform will not adopt blockchain technology at this time. When consumer privacy concerns continue to increase (white areas in Fig.8), blockchain technology will be detrimental to platforms, providers, and consumers.

6 Conclusion

Although the adoption of blockchain technology can improve the transparency of the product and disclosure of the information to the consumer, it also probably make in a risk of consumer privacy leakage. Therefore, we consider a two-stage supply chain comprising a platform and a supplier and investigate the blockchain adoption strategy of the platform under the consumer's transparency awareness and privacy concerns. We consider two scenarios, platform with blockchain adoption(B) otherwise (N). we compare the equilibrium results through the Stackelberg game between the platform and supplier. In addition, we analyze the conditions under which the supplier, platform, consumer, and social welfare can benefit from blockchain adoption. Some managerial implications are founded.

We first investigate the platform's transparency decision and pricing decision for both platform and supplier. We find that the platform's transparency level and the retail price will increase with the consumers' transparency awareness and decrease with the

consumers' privacy concerns. This is when the consumers' transparency awareness is high and privacy concern is low, it is more favorable for the platform to adopt blockchain. Additionally, when consumers' transparency awareness is low, the platform will increase the retail price as the proportional cost of blockchain technology increases. Counterintuitively, when transparency awareness is high, the platform will even decrease the retail price as the increasing proportional cost of blockchain technology.

Regarding the supply chain members' preferences for blockchain adoption, we find that when the transparency cost is sufficiently low, it is beneficial for the platform to adopt blockchain technology. This indicates that when the platform considers whether to adopt blockchain technology, she should weigh the advantages of quality information disclosure between the cost of transparency. Interestingly, blockchain adoption is beneficial for the supplier and the whole supply chain but hurts the platform under a certain threshold. Specifically, the platform is more sensitive to the increase in consumers' privacy concerns and transparency costs. The underlying reason is that the platform bears the cost of information disclosure. Additionally, we find that there exists a 'win-win-win' strategy under certain conditions when transparency awareness is high, and privacy concern is low, in which the application of blockchain technology will benefit the supplier, platform, and consumers.

Our research can be extended in the following directions. Firstly, we standardized the fixed cost of blockchain technology to zero. In fact, the fixed cost of blockchain adoption is high. In future research, we cloud investigate the impact of fixed cost in blockchain adoption on the supply chain. Secondly, we consider only one supplier in the platform. We could consider a duopoly situation in future research.

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