*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 1053-1064*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

# Incentive Mechanism for E-commerce Platform Sellers' Choice of Using Blockchain with Quality Uncertainty

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***Abstract:***

The incentive mechanism for E-commerce platform sellers adopting blockchain when there exists consumer uncertainty about the quality is explored in this study. The results show that the main tradeoff comes from the valuation increased by the additional data offered by blockchain and the cost investing and applying blockchain. When the fixed cost of investing blockchain is very high, even with the discount policy offered by the platform, the seller still cannot gain positive profit and therefore will not choose to adopt blockchain. When the fixed cost is in medium range, a proper discount policy is able to allow the seller to benefit enough to cover the cost and therefore be willing to invest in blockchain. And when the fixed cost is low, the seller will always choose to use blockchain regardless of the discount policy.

***Keywords****: Incentive mechanism, Quality uncertainty, E-commerce platform, Blockchain.*

## I. INTRODUCTION

Quality is one of the most important factors influencing consumers' valuation and then purchase decision about one product. However, due to information asymmetry, consumers may be uncertain about the product even when the seller offers high quality products. Especially when the product is selling through E-commerce platform and cannot be seen or touched. The valuation uncertainty, compounded with limited information reduces the willingness of consumers to pay for high quality, resulting a significant negative impact on the sales. Therefore, both the seller and the platform have the incentive to improve this situation.

In recent years, blockchain as a new emerged technology, has been applied in many areas, including banking [1], healthcare [2, 3], environment [4], agri-food 4.0 [5] and so on. With blockchain technology, data can be secured stored safely and consumers can examine all information and verify products' authenticity. Consumers then may raise the confidence and valuation of the product with improved traceable information. For example, by using blockchain technology, Ikea can guarantee the whole process

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from the raw materials is controlled and the final products are indeed manufactured from the specific wood stated [6]. Consumers can scan the quick response code to obtain more information about products, which will reduce their uncertainty and contribute to their evaluation. Therefore, blockchain provides a feasible solution for the seller.

However, additional cost will occur if the seller decides to use blockchain. One main part is the fixed cost investing all the equipment and training. Also, there will be additional daily operational cost. This is part of the reasons not all firms adopting blockchain even it brings advantages in a lot of aspects.

Therefore, the questions naturally arise: when the seller should consider adopt blockchain, whether should the platform offer incentive policy to the seller, and how the policy works? To address these questions, an analytical model is developed in section 2.1 and the benchmark case in which the platform offers no encouragement and the seller chooses not to invest in section 2.2. And then the cases where one of them differs from the benchmark case are discussed in section 3.1 and 3.2. The situation where both of them make the different choices is analyzed in section 3.3 and comparisons are made in section 3.4.

## II. THE MODEL

### 2.1 Model and Assumptions

Consider a single-period model with one seller selling through one platform.

The seller. The product quality sold by the seller can be demonstrated as $q=\theta+I$ (See Chen and Deng [7], Dowlatshahi and Urias [8] for similar assumptions). The first part $\theta$ represents the inherent quality of the product, which is also the prior belief of the buyer. The second part $I$ shows the seller's private investment level on quality. Also, cost $c$ exists for each unit sold. There are two decisions need to be made by the seller. One is the per unit selling price $p$. The other is whether adopt the technology blockchain with fixed investment cost $c_B$.

Consumers. The valuation of consumers depends on the belief about the quality. It can be denoted by $v=\theta+b\cdot I$, where $\theta$ is uniformly distributed on $[\underline{\theta},\bar{\theta}]$ and $b\in[0,1]$ represents the information learned about the quality from the blockchain. So $b$ is positive if the seller chooses to invest in blockchain and zero otherwise.

The platform. Two parts of decisions are made by the platform. When the seller sells on the platform, there is a variable fee $c_f$ charged for per unit product sold. Besides this, the platform also need to decide whether to encourage the seller through offering a discount policy ($\alpha,\beta$), where $\alpha,\beta\in[0,1]$ and corresponding to the fixed and variable fee respectively.

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The sequence of events. As discussed above, each party makes his/her own decision and forms the following event sequence.

(1) The platform announces the policy ($c_F, c_f$) for selling through the platform and the encouragement policy ($\alpha, \beta$) for sellers adopting blockchain.

(2) The seller observes the policies announced by the platform and then decides whether to invest in blockchain. The fixed cost $c_B$ occurs if invested. Then the seller sets the per unit price $p$ for products selling on the platform.

(3) Each consumer makes the purchase decision based on his or her valuation $v = \theta + b \cdot I$, which will be affected by the information offered through blockchain.

(4) The seller receives the profit from selling the products and makes the payment to the platform according to the policies.

In the following sections, we use superscripts $R$ and $P$ to denote the notations related to the seller and the platform, respectively. And use subscripts $N$ and $B$ to denote the case of no blockchain and with blockchain, respectively. We also use $E$ to denote the cases with encouragement from the platform.

2.2 Benchmark Case: No Blockchain & No Discount

We first consider the benchmark case where the seller does not invest in blockchain and the platform offers no discount. Then the demand is $s_N = \bar{\theta} - p$. The profit for the seller and the platform is $\pi_N^R = \left(p - c - c_f\right) s_N$ and $\pi_N^P = c_f s_N$, respectively.

Apply backward analysis for the problem. Consider the seller's decision given the fee policy from the platform. The following Lemma can be obtained.

Lemma 1. Given the fee policy $c_f$, the optimal price of the seller is $p_N^*(c_f) = \dfrac{\bar{\theta} + c + c_f}{2}$.

Proof. Given $c_f$, the profit of the seller is

$$\pi_N^R = \left(p - c - c_f\right) s_N = (p - c - c_f)(\bar{\theta} - p). \tag{1}$$

Since

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$$\frac{d\pi_N^R}{dp} = \bar{\theta} - 2p + c + c_f \tag{2}$$

and

$$\frac{d^2\pi_N^R}{dp^2} = -2 < 0 , \tag{3}$$

We know that $\pi_N^R$ is concave in $p$. And then FOC gives the optimal price, which is

$$p_N^*(c_f) = \frac{\bar{\theta} + c + c_f}{2} . \tag{4}$$

End of proof.

Lemma 1 shows that the optimal price of the seller equally depends on the consumers' valuation, the per unit variable cost of the product and also the per unit fee charged by the platform. With the best response of the seller, the platform is able to make the optimal decision about the policy and then the seller can also obtain the optimal decision as shown in the following proposition.

Proposition 1. When the seller does not invest in blockchain and the platform offers no discount, (1) the optimal price of the seller is $p_N^* = \frac{3\bar{\theta} + c}{4}$, and the optimal profit is $\pi_N^{R*} = \left(\frac{\bar{\theta} - c}{4}\right)^2$; (2) the optimal fee of the platform is $c_{fN}^* = \frac{\bar{\theta} - c}{2}$, and the optimal profit is $\pi_N^{P*} = \frac{\left(\bar{\theta} - c\right)^2}{8}$.

Proof. Following Lemma 1, when

$$p_N^*(c_f) = \frac{\bar{\theta} + c + c_f}{2} , \tag{5}$$

the profit of the platform is then

$$\pi_N^P = c_f \cdot \frac{\bar{\theta} - c - c_f}{2} . \tag{6}$$

Since

$$\frac{d\pi_N^P}{dc_f} = \frac{\bar{\theta} - c - 2c_f}{2} \tag{7}$$

and

$$\frac{d^2\pi_N^P}{d{c_f}^2} = -1 < 0 , \tag{8}$$

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We know that $\pi_N^P$ is concave in $c_f$. Let $\frac{d\pi_N^P}{dc_f}=0$, we can have the optimal fee of the platform is

$$c_{fN}^* = \frac{\bar{\theta}-c}{2}. \tag{9}$$

Then the profit of the seller is

$$\pi_N^{R*} = \left(\frac{\bar{\theta}-c}{4}\right)^2 \tag{10}$$

and the profit of the platform is

$$\pi_N^{P*} = \frac{\bar{\theta}-c}{2}\cdot\frac{\bar{\theta}-c}{4} = \frac{(\bar{\theta}-c)^2}{8}. \tag{11}$$

End of Proof.

The optimal decisions of both the seller and the platform are determined by the upbound valuation of consumers and the variable cost of the product. While the higher valuation upbound and the lower variable cost bring more profit for both parties, these two factors have different influence on the optimal decisions. The optimal price of the seller and the optimal fee are both increasing with the increasing valuation upbound. But the optimal price increases and the optimal fee decreases when the variable cost increase. This is due to the seller need more compensation for higher cost and the platform have to sacrifice for more sales.

## III. ANALYSIS AND DISCUSSION

### 3.1 Blockchain & No Discount

Given the fee policy from the platform $c_f^* = \frac{\bar{\theta}-c}{2}$, consider the seller's choice of whether to invest in blockchain while the platform does not offer discount. Then the demand is

$$s_B = \bar{\theta} - p + bI. \tag{12}$$

The profit of the seller and the platform is

$$\pi_B^R = \left[p - c - c_b - c_f^*\right] s_B - c_B \tag{13}$$

and

$$\pi_B^P = c_f^* s_B, \tag{14}$$

respectively. Then the optimal decisions can be obtained as shown in the following proposition.

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Proposition 2. When the seller chooses to adopt blockchain and the platform offers no discount, (1) the optimal price of the seller is $p_B^* = \frac{3\bar{\theta} + 2bI + c + 2c_b}{4}$, and the optimal profit is $\pi_B^{R*}$ = $\left[\frac{\bar{\theta} - c + 2(bI - c_b)}{4}\right]^2 - c_B$; (2) the optimal profit of the platform is $\pi_B^{P*} = \frac{(\bar{\theta} - c)\left[\bar{\theta} - c + 2(bI - c_b)\right]}{8}$.

Proof. When the seller adopts blockchain, the profit is

$$\pi_B^R = \left(p - c - c_b - c_f^{\ *}\right)\left(\bar{\theta} - p + bI\right) - c_B. \tag{15}$$

Take the first and the second derivative of $p$, we have

$$\frac{d\pi_B^R}{dp} = \bar{\theta} - 2p + bI + c + c_b + c_f^{\ *} \tag{16}$$

and

$$\frac{d^2\pi_B^R}{dp^2} = -2 < 0. \tag{17}$$

Then we know that $\pi_B^R$ is concave in $p$. Let $\frac{d\pi_B^R}{dp} = 0$, we can have the optimal price of the seller is

$$p_B^* = \frac{\bar{\theta} + bI + c + c_b + c_f^{\ *}}{2} = \frac{3\bar{\theta} + 2bI + c + 2c_b}{4} \tag{18}$$

and the corresponding profit is

$$\pi_B^{R*} = \left(\frac{\bar{\theta} + bI - c - c_b - c_f^{\ *}}{2}\right)^2 - c_B = \left[\frac{\bar{\theta} - c + 2(bI - c_b)}{4}\right]^2 - c_B. \tag{19}$$

Then the profit of the platform is

$$\pi_B^{P*} = \frac{\bar{\theta} - c}{2} \cdot \frac{\bar{\theta} - c + 2(bI - c_b)}{4} = \frac{(\bar{\theta} - c)\left[\bar{\theta} - c + 2(bI - c_b)\right]}{8}. \tag{20}$$

End of Proof.

Now with blockchain, the benefit of the information and the cost also play important roles in the seller's optimal decision. It is easy to tell that the seller will raise the optimal price. And while the profit of the seller is not clear due to the tradeoff between the benefit and the cost since the prior increases consumers' valuation and allows the seller to charge higher price and the latter increase the seller's cost and lowers the total profit, it is clear that the platform's profit will be improved as long as the value brought by blockchain is higher than the cost.

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3.2 Blockchain & Discount

Given the fee policy from the platform $c_f^{\,*} = \dfrac{\bar{\theta} - c}{2}$, consider the seller's choice of whether to invest in blockchain while the platform offers encouragement discount policy ($\alpha, \beta$). The demand is

$$s_{BE} = \bar{\theta} - p + bI \tag{21}$$

and the profit of the seller is

$$\pi_{BE}^{R} = \left[ p - c - c_f^{\,*} - (1-\beta)c_b \right] s_{BE} - (1-\alpha)c_B . \tag{22}$$

The profit of the platform with discount is

$$\pi_{B}^{P} = \left( c_f^{\,*} - \beta c_b \right) s_{BE} - \alpha c_B . \tag{23}$$

Proposition 3. When the seller chooses blockchain and the platform offers the discount policy, (1) the optimal price of the seller is $p_{BE}^{*} = \dfrac{3\left(\bar{\theta} + bI\right) + c + c_b}{4}$, and the optimal profit is $\pi_{BE}^{R*} = \left( \dfrac{\bar{\theta} + bI - c - c_b}{4} \right)^2 - (1-\alpha)c_B$; (2) the optimal discount policy of the platform is $\beta_{BE}^{*} = \dfrac{c_b - bI}{2c_b}$, and the optimal profit is $\pi_{BE}^{P*} = \dfrac{\left(\bar{\theta} + bI - c - c_b\right)^2}{8} - \alpha c_B$.

Proof. When the seller adopts blockchain, the profit is then

$$\pi_{BE}^{R} = \left[ p - c - c_f^{\,*} - (1-\beta)c_b \right] \left( \bar{\theta} - p + bI \right) - (1-\alpha)c_B . \tag{24}$$

Take the first and the second derivative of $p$, we have

$$\frac{d\pi_{BE}^{R}}{dp} = \bar{\theta} - 2p + bI + c + c_f^{\,*} + (1-\beta)c_b \tag{25}$$

and

$$\frac{d^2\pi_{BE}^{R}}{dp^2} = -2 < 0 . \tag{26}$$

Then we know that $\pi_{BE}^{R}$ is concave in $p$. Let $\dfrac{d\pi_{BE}^{R}}{dp} = 0$ and we can obtain the optimal price of the seller is

$$p_{BE}^{*} = \frac{\bar{\theta} + bI + c + c_f^{\,*} + (1-\beta)c_b}{2} . \tag{27}$$

The profit of the platform is then

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ISSN: 1520-0191
July-August 2022 Page No. 1053-1064
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

$$\pi_{BE}^{P}=-\alpha c_B+\left(c_f^{\ *}-\beta c_b\right)\cdot\frac{\overline{\theta}+bI-c-c_f^{\ *}-(1-\beta)c_b}{2}. \tag{28}$$

Since the profit is monotone in $\alpha c_B$, which is bounded by the practice. Then divide the profit to be two parts $\pi_{BE}^{PF}$ and $\pi_{BE}^{PC}$, where

$$\pi_{BE}^{PF}=-\alpha c_B \tag{29}$$

And

$$\pi_{BE}^{PC}=\left(c_f^{\ *}-\beta c_b\right)\cdot\frac{\overline{\theta}+bI-c-c_f^{\ *}-(1-\beta)c_b}{2}. \tag{30}$$

Since

$$\frac{d\pi_{BE}^{PC}}{d\beta}=-\frac{c_b}{2}\left(2\beta c_b-2c_f^{\ *}+\overline{\theta}+bI-c-c_b\right) \tag{31}$$

and

$$\frac{d^2\pi_{BE}^{PC}}{d\beta^2}=-c_b^{\ 2}<0, \tag{32}$$

we know that $\pi_{BE}^{PC}$ is concave in $\beta$. Let $\frac{d\pi_{BE}^{PC}}{d\beta}=0$, we have the optimal discount is

$$\beta_{BE}^{*}=\frac{2c_f^{\ *}-\left(\overline{\theta}+bI-c-c_b\right)}{2c_b}=\frac{c_b-bI}{2c_b}. \tag{33}$$

Then the optimal price of the seller is

$$p_{BE}^{*}=\frac{3\left(\overline{\theta}+bI\right)+c+c_b}{4} \tag{34}$$

and the corresponding profit is

$$\pi_{BE}^{R*}=\left(\frac{\overline{\theta}+bI-c-c_b}{4}\right)^2-(1-\alpha)c_B. \tag{35}$$

The optimal profit of the platform is

$$\pi_{BE}^{P*}=\frac{\left(\overline{\theta}+bI-c-c_b\right)^2}{8}-\alpha c_B. \tag{36}$$

End of proof.

Compare the profit of the platform with no discount policy, as long as the value brought by blockchain is higher than the cost and set the discount about the fixed cost at certain range, the profit could still be higher than that under no discount, which outperforms the profit with no blockchain. Therefore, the platform always has the incentive to encourage the seller to choose blockchain.

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Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

The seller's optimal price has the same factors as the case without discount but higher than before. Yet the optimal profit is not easy to tell since when the seller gains more benefit from the information, the fixed cost still need to be taken into consideration.

3.3 Comparison

In this subsection, we focus on the seller's choice under the platform's policy. We first consider the cases with no discount offered.

Proposition 4. When the platform offers no discount, the seller's decision about blockchain is (1) if $\frac{\left(\bar{\theta}-c+bI-c_b\right)\left(bI-c_b\right)}{4}\geq c_B$, the seller should choose to invest in blockchain; (2) if $\frac{\left(\bar{\theta}-c+bI-c_b\right)\left(bI-c_b\right)}{4}< c_B$, the seller should not choose to adopt blockchain.

Proof. Compare the seller's optimal profit of with and without blockchain while the platform offers no discount, we have

$$\pi_B^{R*}-\pi_N^{R*}=\left[\frac{\bar{\theta}-c+2\left(bI-c_b\right)}{4}\right]^2-c_B-\left(\frac{\bar{\theta}-c}{4}\right)^2=\frac{\left(\bar{\theta}-c+bI-c_b\right)\left(bI-c_b\right)}{4}-c_B. \tag{37}$$

Then we can get that $\pi_B^{R*}>\pi_N^{R*}$ if

$$\frac{\left(\bar{\theta}-c+bI-c_b\right)\left(bI-c_b\right)}{4}\geq c_B, \tag{38}$$

which means the seller gains more profit if adopting blockchain. And if

$$\frac{\left(\bar{\theta}-c+bI-c_b\right)\left(bI-c_b\right)}{4}< c_B, \tag{39}$$

the seller should not invest in blockchain since $\pi_N^{R*}>\pi_B^{R*}$. End of Proof.

Observe the inequation, we can see that whether the seller chooses to adopt blockchain or not mainly depend on two parts. One is the per unit benefit, which is determined by the value raised by the information and the per unit cost for applying blockchain. If the per unit benefit is negative, the seller should not consider investing. The other part is the fixed cost. Though the positive per unit benefit allows the seller to gain more profit during daily operations, the overall benefit is still negative if the fixed cost cannot be well covered.

Since the cost of adopting blockchain is on the seller, and the platform can gain profit from more sales, the platform has the incentive to offer the discount policy. The effect of such policy is explored in the following propositions.

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Proposition 5. The effect of discount policy from the platform for the seller's decision adopting blockchain is (1) if $M \geq (1-\alpha)c_B$, the discount policy works and the seller is encouraged to adopt blockchain; (2) if $M < (1-\alpha)c_B$, the discount policy fails and the seller chooses not to invest in blockchain; where $M = \frac{\left[2\left(\bar{\theta}-c\right)+bI-c_b\right]\left(bI-c_b\right)}{16}$.

Proof. Compare the seller's optimal profit of with and without blockchain while the platform offers discount, we have

$$\pi_{BE}^{R*} - \pi_N^{R*} = \left(\frac{\bar{\theta}+bI-c-c_b}{4}\right)^2 - (1-\alpha)c_B - \left(\frac{\bar{\theta}-c}{4}\right)^2$$
$$= \frac{\left[2\left(\bar{\theta}-c\right)+bI-c_b\right]\left(bI-c_b\right)}{16} - (1-\alpha)c_B. \tag{40}$$

Let

$$M = \frac{\left[2\left(\bar{\theta}-c\right)+bI-c_b\right]\left(bI-c_b\right)}{16}. \tag{41}$$

Then when $(1-\alpha)c_B < M$, we have that $\pi_{BE}^{R*} > \pi_N^{R*}$, which means the discount policy works and the seller is encouraged to adopt. And when

$$(1-\alpha)c_B > \frac{\left[2\left(\bar{\theta}-c\right)+bI-c_b\right]\left(bI-c_b\right)}{16}, \tag{42}$$

the discount policy fails since $\pi_N^{R*} > \pi_{BE}^{R*}$, which means the profit of the seller does not improved therefore choosing not to invest in blockchain. End of proof.

The seller's choice of adopting blockchain or not still depends on the trade off between the benefit gained from improved consumers' valuation. Only this time, with the discount from the platform, the chance for the seller to obtain positive overall benefit is improved.

Proposition 6. When the platform offers discount policy, the effect of encouragement for the seller's profit is (1) if $\alpha c_B \geq \frac{\left[2\left(\bar{\theta}-c\right)+3\left(bI-c_b\right)\right]\left(bI-c_b\right)}{16}$, the profit of the seller is improved by the encouragement policy; (2) if $\alpha c_B < \frac{\left[2\left(\bar{\theta}-c\right)+3\left(bI-c_b\right)\right]\left(bI-c_b\right)}{16}$, the discount policy shows no effect of encouragement, the profit of the seller is higher with no discount.

Proof. Compare the profit of the seller adopting blockchain with and without discount, we have

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$$\pi_{BE}^{R*}-\pi_{B}^{R*}=\left(\frac{\bar{\theta}+bI-c-c_b}{4}\right)^2-(1-\alpha)c_B-\left[\frac{\bar{\theta}-c+2(bI-c_b)}{4}\right]^2+c_B$$
$$=\alpha c_B-\frac{\left[2(\bar{\theta}-c)+3(bI-c_b)\right](bI-c_b)}{16}. \qquad (43)$$

It is easy to see that when

$$\alpha c_B \geq \frac{\left[2(\bar{\theta}-c)+3(bI-c_b)\right](bI-c_b)}{16}, \qquad (44)$$

the profit of the seller is improved under discount policy which yields $\pi_{BE}^{R*}>\pi_{B}^{R*}$. And when

$$\alpha c_B < \frac{\left[2(\bar{\theta}-c)+3(bI-c_b)\right](bI-c_b)}{16}, \qquad (45)$$

the profit of the seller is higher with no discount $\pi_{B}^{R*}>\pi_{BE}^{R*}$. End of proof.

However, when the discount policy improves the chance of the seller adopting blockchain, it does not work for all circumstances. In the case where the fixed cost is very high or very low, the encouragement policy fails. This is because when the fixed cost is very high, the platform is not able to offer enough compensation for the seller. And when the fixed cost is low enough, there is no need for the discount since the seller will chooses to invest anyway.

## IV. CONCLUSION

The choice about blockchain of a seller selling on E-commerce platform with private quality information is studied. We first discuss the benchmark case where the seller has no blockchain and the platform offers no encouragement policy. In this case, the optimal decisions of both sides are determined by the consumers' valuation and the per unit variable cost of the product.

Based on this, we then explore the case where the seller adopts blockchain. We find that in this case, the optimal price from the seller is increased and the profit of the platform is improved as long as the information brough by blockchain is positive during daily operations. And then the discount policy from the platform is considered. The optimal price is further increased and the performance on the platform's profit is still valuable when the benefit from sales outperforms the fixed cost of investing blockchain.

Regarding the overall decision of the seller, we find that it shows the pattern of three stages. The first stage is when the fixed cost of investing blockchain is very high. In this stage, the fixed cost is so high that the platform is not able to offer the discount or even with the discount, the seller still cannot afford the total cost. Therefore, the platform offers no discount and the seller chooses no blockchain.

The second stage is when the fixed cost is in the medium range. In this stage, the seller is able to improve the sales with blockchain and gain certain benefits during daily operations. And the platform also benefits from the increased sales. However, the fixed cost is still a problem for the seller. So, if the platform can offer proper support by certain discount policy, the seller will be encouraged to adopt blockchain. Otherwise, the seller has to quit due to the heavy fixed cost.

The third stage is when the fixe cost is relatively low. In this stage, the fixed cost can be easily covered by the improvement of sales. Therefore, the seller will always choose to adopt blockchain regardless of the platform's discount policy. Then the best choice of the platform is not to offer the discount.

Future research can be continued for more general cases. And more practical or real applications can be discussed.

## ACKNOWLEDGEMENTS

This research was supported by National Natural Science Foundation of China (No.72003081).

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