Pricing Based on Agricultural Product Freshness and Traceability Level

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Abstract. The supply chain of agricultural products is long and the information is scattered, which is easy to break. The use of blockchain can improve consumer trust in products, in order to explore how to obtain the optimal profits from pricing, this paper studies the supply chain composed of suppliers, e-commerce and consumers. Considering the impact of product freshness and traceability level, and constructing four game models led by e-commerce and followed by suppliers, to analyze the changes of wholesale price, the selling price, market demand and the whole supply chain profits, as well as the optimal traceability level of suppliers and e-commerce. The results show that when investing in blockchain, the pricing of suppliers and e-commerce will increase, and the degree is related to consumers' freshness and traceability preference, and the greater the preference, the higher the price is likely to be.

Keywords: Blockchain; Traceability; Pricing.

1 Introduction

The rise of e-commerce has led to an increasing number of products from unknown brands, food safety is getting more and more attention, in particular, agricultural products. Traceability techniques are often used to monitor the status of products during distribution, blockchain has gained widespread attention because of its immutability, traceability and anti-counterfeiting features[1]. In reality, there are some companies that have used blockchain, such as Such as Zhongan Technology and Wal-Mart[2]. Research shows that consumers prefer to buy traceable agricultural products [3].However, using blockchain can lead to price increases, and business managers need to balance their own profits and consumer inputs. Therefore, this paper starts from the investment decision of agricultural product to study how to price, and finally to achieve a win-win situation.

2 Literature Review

2.1 Tracing Technology

Traceability is defined as the ability to access any or all information related to the food under consideration, throughout its entire lifecycle, using recorded identifications [4]. There are many traditional traceability techniques, such as direct traceability techniques (QR code, bar code) and indirect traceability techniques (RFID, NFC, WSN) [5], but they suffer from the risk of

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information leakage and have requirements for the usage environment. Blockchain can fills these gaps well and now is widely favored by scholars [6]. Chen, Q., Wang, G.N., et al. [7] analyzed the impact of blockchain on consumers' repurchase intention. Zheng, T., Ye, Z. [8] deduced that blockchain traceability can improve market demand and the revenue of each member of the supply chain. Feng, Z.W., Li, G.P., et al. [9] introduced blockchain into the green supply chain. Huo, H., Zhong, H.Y. [10] proved that there is free-riding behavior. Hu, S.S., Zhou, L.Y., et al.[11] inferred that profits are related to blockchain technology learning efficiency.

2.2 Product Pricing

Whether to invest in traceability technology has a great impact on pricing, and directly affects the profit distribution of supply chain. Few studies have combined blockchain traceability level and product characteristics to price. Wang, J.B., Zhang, L.D. [12] explored the blockchain investment scheme corresponding to the cost effect. Liu, L., Li, F.T. [13] studied the threshold of blockchain investment cost. Yao, F.M., Ju, J.Y., et al. [14] set prices based on government subsidies and e-commerce altruistic preference. Chen, C.H., Li, Y., et al. [15] introduced the cost change coefficient to explore the traceability. Zheng, Q., Fan, T.J., et al. [16] investigated the optimal pricing of e-commerce self-pickup and supplier delivery to warehouse under the pre-warehouse mode. Liu, P., Li, M.J., Si, H.P., et al. [17] has studied centralized and decentralized pricing in blockchain. Tan, C.Q., Zeng, Y.Q. [18] discussed the retailer's two-stage pricing strategy during the full price period and the discount period.

In summary, the existing researches mainly focus on general product, without considering the characteristics of agricultural products and blockchain input level. This paper considers the products freshness and traceability level, and studies the impact of traceability investment on wholesale prices, selling prices and demand, and how different investors affect pricing. The research results enrich the operation management of blockchain to a certain extent, and also provide theoretical references for product pricing decisions.

3 Analysis

This paper studies a three-level supply chain consisting of supplier, e-commerce and consumers, and establishes game models in which the e-commerce leads and the supplier follows. Investing in blockchain can improve the competitiveness of products, this paper can be divided into four cases according to suppliers and e-commerce whether to invest. Case1: Neither supplier nor e-commerce invest in blockchain SE. Cases 2: Suppliers invest and e-commerce don't invest $\overline{S}E$. Case 3: Supplier don't invest and e-commerce invest $S\overline{E}$. Case4: Both supplier and e-commerce invest, $\overline{S}\overline{E}$.

3.1 Variables Description

Define the variables and their meanings in **Table 1** before modeling.

Table 1. Variables definition.

Variables	meanings
C	The supplier unit fixed cost
W	Unit wholesale cost
D	Market demand without investment traceability
P	The unit price of the e-commerce
μ	Cost factor,
si	Traceability level, i=1,2
α	Price preference, 0<α<1
β	Freshness preference, 0<β<1
θ	Traceability preference, 0<θ<1

3.2 Functions Description

Agricultural products are easy to deteriorate, the longer the transportation time, the greater the loss. Freshness function sees equation (1), suppose the life cycle is T, V(T)=0.

$$v(t)=v_0 e^{-\eta t} \quad (1)$$

Suppose the initial market demand is 1, demand influenced by price, freshness[19]and traceability level[7], the demand function see equation (2). If blockchain is not used, $s_i = 0$.

$$D=1-\alpha p+\beta v(t)+\theta s_i \quad (2)$$

The supplier profits see equation (3). E-commerce profits see equation (4), traceability costs are $\frac{1}{2}\mu s_i^2$ [9][11]. If blockchain is not used, $s_i = 0$.

$$\Pi_s=(W-C)D-\frac{1}{2}\mu s_1^2 \quad (3)$$

$$\Pi_E=(P-W)D-\frac{1}{2}\mu s_2^2 \quad (4)$$

3.3 Methodology

After defining these functions, backward introduction can be used to obtain the optimal results, it's a method to analyze from the last stage of the dynamic game, and gradually summarize the selection strategies of the players in each stage. It can be divided into four steps. (a) Let's set $\frac{\partial \Pi_E}{\partial P}=0$, to figure out P which depends on W.(b) Let's set $\frac{\partial \Pi_S}{\partial W}=0$, the optimal W can be obtained. (c) By substituting W into P and equations (2)(3)(4), then can get the optimal price $P1^*$, the optimal demand D^*, and the maximum profits of supplier, e-commerce and the whole supply chain.(d) When $\frac{\partial \Pi_{s_2}}{\partial_{s1}}=0$, $\frac{\partial^2 \Pi_{s_2}}{\partial_{s1^2}}<0$.$\frac{\partial \Pi_{E3}}{\partial_{s2}}=0$, $\frac{\partial^2 \Pi_{E3}}{\partial_{s2^2}}<0$. It is possible to find the optimal traceability level s_1 and s_2, see equation (5) and (6).

$$s_1=\frac{\theta(1+\beta v(t)\text{-}\alpha c)}{4\alpha\mu-\theta^2}, when\ satisfied\ \theta^2<4\alpha\mu. \quad (5)$$

$$s_2=\frac{\theta(1+\beta v(t)\text{-}\alpha c)}{8\alpha\mu-\theta^2}, when\ satisfied\ \theta^2<8\alpha\mu. \quad (6)$$

When it comes to case 4, suppose demand affected by suppliers and e-commerce is independent, so the demand function is equation (7).

$$D=1\text{-}\alpha p+\beta v(t)+\theta(s_1+s_2) \quad (7)$$

3.4 Results

By backward induction, the wholesale price, selling price, demand and supply chain profits in four cases can be obtained, see **Table 2.**

Table 2. research results.

cases	SE	$\bar{S}E$
results	$W1=\frac{1+\beta v(t)+\alpha c}{2\alpha}$ $P1=\frac{3+3\beta v(t)+\alpha c}{4\alpha}$ $D1=\frac{1+\beta v(t)\text{-}\alpha c}{4}$ $\Pi_{s1}=\frac{(1+\beta v(t)\text{-}\alpha c)^2}{8\alpha}$ $\Pi_{E1}=\frac{(1+\beta v(t)\text{-}\alpha c)^2}{16\alpha}$	$W2=\frac{1+\beta v(t)+\theta s_1+\alpha c}{2\alpha}$ $P2=\frac{3+3\beta v(t)+3\theta s_1+\alpha c}{4\alpha}$ $D2=\frac{1+\beta v(t)+\theta s_1\text{-}\alpha c}{4}$ $\Pi_{s2}=\frac{(1+\beta v(t)+\theta s_1\text{-}\alpha c)^2}{8\alpha}\text{-}\frac{1}{2}\mu {s_1}^2$ $\Pi_{E2}=\frac{(1+\beta v(t)+\theta s_1\text{-}\alpha c)^2}{16\alpha}$
cases	$S\bar{E}$	$\bar{S}\bar{E}$
results	$W3=\frac{1+\beta v(t)+\theta s_2+\alpha c}{2\alpha}$ $P3=\frac{3+3\beta v(t)+3\theta s_2+\alpha c}{4\alpha}$ $D3=\frac{1+\beta v(t)+\theta s_2\text{-}\alpha c}{4}$ $\Pi_{s3}=\frac{(1+\beta v(t)+\theta s_2\text{-}\alpha c)^2}{8\alpha}$ $\Pi_{E3}=\frac{(1+\beta v(t)+\theta s_2\text{-}\alpha c)^2}{16\alpha}\text{-}\frac{1}{2}\mu {s_2}^2$	$W4=\frac{1+\beta v(t)+\theta(s_1+s_2)+\alpha c}{2\alpha}$ $P4=\frac{3+3\beta v(t)+3\theta(s_1+s_2)+\alpha c}{4\alpha}$ $D4=\frac{1+\beta v(t)+\theta(s_1+s_2)\text{-}\alpha c}{4}$ $\Pi_{s4}=\frac{(1+\beta v(t)+\theta(s_1+s_2)\text{-}\alpha c)^2}{8\alpha}\text{-}\frac{1}{2}\mu {s_1}^2$ $\Pi_{E4}=\frac{(1+\beta v(t)+\theta(s_1+s_2)\text{-}\alpha c)^2}{16\alpha}\text{-}\frac{1}{2}\mu {s_2}^2$

It can be seen from the results that when blockchain is not used, the decisions of suppliers and e-commerce are affected by the loss and freshness of agricultural products in the circulation process. After investing in blockchain, the profits of supply chain members and the whole have changed, and they are mainly affected by the traceability level.

4 Conclusions

(1) The traceability level is related to blockchain cost factor μ, traceability preference θ, and price preference α. When the traceability preference θ increases, the more trust consumers have in the products, supply chain members tend to set higher traceability level which constrained by traceability costs μ.

(2) In reality, consumer demand for agricultural products freshness is gradually increasing, and they are willing to buy traceable products, so the market demand D becomes larger. Meanwhile, supply chain members increase their pricing in order to obtain more profits. If traceability level increases by one unit, W increases by $\frac{\theta}{2\alpha}$ units, P increases by $\frac{3\theta}{4\alpha}$ units, and the demand increases by $\frac{\theta}{4}$ units. In other words, when agricultural products with high prices and low freshness, market demand will be weakened and consumers' trust will decline, which is not conducive to the healthy development of the supply chain of agricultural products.

(3) By comparison, profits of supplier and e-commerce are higher after investing in blockchain, when only one member invests in blockchain, the other one appears free-riding behavior, the more benefits a free-riding gets, the less incentive it has to invest in the blockchain. Case 4 can be adopted to solve this problem, that is, when $\Pi_{s4} > \Pi_{s3}$, $\Pi_{E4} > \Pi_{E2}$, $\theta^2 < 4\alpha\mu$, it can ensure supplier and e-commerce profits are relatively optimal.

Freshness and traceability level are important factors in pricing. Using the traceability function of blockchain can improve the transparency of the supply chain and reduce the loss of freshness in the transportation process, but a higher traceability level also means higher input costs, managers should balance traceability preference and blockchain input costs when pricing. Using contracts to balance the input of each member will be the direction of future research.

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