Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 14, No. 1, 2024

An analysis of Strategies for Adopting Blockchain Technology in Fresh Product Supply Chain Under Freshness Misreporting

Deqiang Fu[1], Min Yang[2, *]

[1] Modern Postal School, Chongqing University of Posts and Telecommunications, China
[2] Modern Postal School, Chongqing University of Posts and Telecommunications, China
* Corresponding author: Min Yang (Email: max9809@foxmail.com)

Abstract: The application of blockchain technology can inhibit producers' freshness misrepresentation in fresh produce supply chains. In this paper, we consider consumers with fresh produce freshness information traceability preference. In a fresh produce supply chain with a single producer and a single seller, the seller's blockchain application decision is studied, the Stackelberg game models of the supply chain members in the two scenarios of the producer misrepresenting freshness and the seller applying blockchain are constructed, and the changes of the equilibrium solutions before and after the application of blockchain technology are analysed. The theoretical proofs and numerical simulation studies show that when the transaction cost is at a certain level, the sellers should choose to apply blockchain technology to improve their own revenue, and the level of applying blockchain technology is affected by the consumer's retrospective preference and the cost coefficient of blockchain technology.

Keywords: Supply chain management, fresh product supply chain, blockchain.

1. Introduction

In 2022, the transaction scale of fresh food e-commerce exceeded 500 billion yuan. With the renewal of the consumption mode and the change of the concept of material demand, consumers are not only concerned about the price of fresh agricultural products, but also pay more attention to its freshness and quality level. The shift in consumer demand has also become a powerful impetus for the supply chain to implement new technologies to improve circulation efficiency. Government departments attach great importance to the development of the fresh produce industry chain. The National Strategic Plan for Quality Agriculture (2018-2022) emphasises the need to improve the level of quality and safety of agricultural products. In recent years, consumer complaints caused by the act of misrepresenting information on fresh agricultural products have increased year by year, and misrepresentation of market quality information on fresh agricultural products has gradually become an issue of concern.

The traditional fresh produce supply chain has relatively long chains, low informatisation and asymmetric supply chain information. Due to the private nature of freshness information, producers often misrepresent the freshness. Reduced authenticity of product information can cause fluctuations in the demand market, resulting in a reduction of supply chain system revenues. Lagging information and price fluctuations between supply and marketing parties in the fresh produce supply chain make transactions and settlements extremely difficult, and transaction costs remain high. Therefore, there is an urgent need for a reliable way to verify the production information of fresh produce in the fresh produce supply chain in order to curb the misrepresentation behaviour of producers and reduce the transaction costs.

One solution to the above troubles is the use of blockchain technology. Blockchain technology is highly effective in facilitating the traceability and transparent management of fresh produce supply chain information, and provides an innovative solution for achieving traceability in the fresh produce supply chain. The application of blockchain technology can ensure that product data such as freshness information is true and complete, and can effectively reduce the transaction costs of the supply chain. Therefore, the openness and transparency of blockchain technology can inhibit producers from misreporting, reduce regulatory costs, transaction risks and complexity, and at the same time improve consumer trust and consumer stickiness.

2. Notations and Problem Description

2.1. Problems description

This paper studies a secondary fresh produce supply chain consisting of a fresh produce producer and a seller, where the producer supplies fresh produce to the seller. Due to the private nature of freshness of fresh produce, the producer may misrepresent the freshness in the case of asymmetric freshness information.So whether sellers should choose to apply blockchain, and what factors are related to the profitable application of blockchain become the key issues of the study. Therefore, this paper constructs a Stackelberg game model in which the producer is the dominant player and the seller follows.

The game process in this model is as follows: the producer supplies fresh produce with production cost c_1 and life cycle T. The seller determines the selling price and the level of blockchain application based on the wholesale price provided by the produce producer, freshness and market demand.

The producer, as the leader, determines the wholesale price and the seller, as the follower. The producer supplies the seller with a fresh product with production cost c_1, announces the wholesale price ω and freshness θ based on the seller's response, and the seller determines the selling price based on the information announced by the producer and puts it on the market, as shown in Fig.1.The residual value of the fresh product is 0.

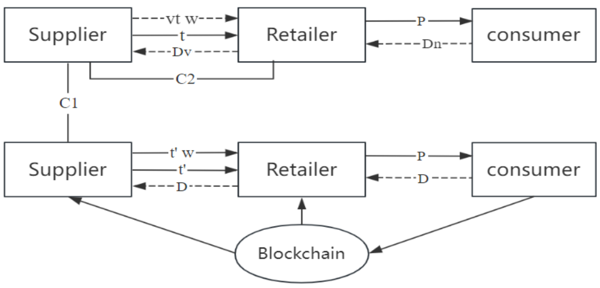

Figure 1. Fresh produce supply chain decision-making model

Fresh produce freshness information is private. In the case of asymmetric freshness information, fresh produce producers may misrepresent the freshness in order to increase profits, affecting the stability of the supply chain. Blockchain technology can realize full traceability of production information related to agricultural products and eliminate the problem of information asymmetry. Sellers can avoid misrepresentation of freshness and pay the cost of blockchain application by applying blockchain technology.

In order to facilitate the modelling analysis, this paper makes the following assumptions:

(1) Consumers trust and are willing to purchase fresh agricultural products with a higher level of blockchain application, and consumer demand is positively related to the level of blockchain technology application.

(2) When blockchain technology is not applied, in order to reach a transaction, fresh produce producers and sellers bear the same transaction cost, which is set as in this paper.

(3) The cost brought by sellers applying blockchain technology is single, which is set as in this paper.

(4) To ensure that the relevant decision variables are positive, it is assumed that the application cost coefficient satisfies .

2.2. Model setup

The freshness of fresh produce decays with the time of production, with a life cycle of T and a time after production of t. The reference sets the function of freshness to $\theta(t) = 1 - t^2/T^2$, $0 \leq t_0 + t_1 < T$, $\theta(t) \in [0,1]$ .The freshness function is $\theta_v(t) = 1 - (vt)^2/T^2$ in the case of misreporting and $\hat{\theta}(t) = 1 - \hat{t}^2/T^2$ in the case of applying blockchain.

In the case of asymmetric information on freshness, fresh produce producers may misrepresent freshness in order to increase the volume of orders from sellers, thereby increasing their own revenue. In this paper, we set the level of misrepresentation to be $0 \leq v \leq 1$, and the published production time to be vt . The information is completely misrepresented at $v = 0$, and the information is completely transparent at $v = 1$.

The market demand of fresh produce is not only affected by the price, but also by the freshness. Referring to the relevant literature, assuming that consumers' preference for freshness information traceability is β , the level of blockchain technology application is g, the potential market demand is α , and the sales price is p, the market demand is $D = \theta(\alpha - bp)$; under the scenario of misreporting the freshness, the market demand is falsely high, which is $D_v = \theta_v(\alpha - bp)$; and the seller applies blockchain technology to shorten the supply chain sales time and accelerate the speed of circulation, and the application of the blockchain scenario, the market demand is $\hat{D} = \hat{\theta}(\alpha - bp + \beta g)$.

Table 1 Definition of model parameters

Symbol	Symbol Description
p	unit sales price of fresh produce
ω	wholesale prices of fresh produce
C_1	unit production costs of agricultural products
C_2	transaction costs per unit of agricultural produce
t	time required for distribution of products
β	level of consumer preference for blockchain
g	level of blockchain technology adoption
v	freshness misrepresentation level
α	market size
T	life cycle of fresh produce
θ	freshness of fresh produce
D	market demand with actual freshness
D_{nv}	market demand under freshness misrepresentation
D_{bd}	market demand under blockchain technology
π_s	producer's profit
π_r	seller's profit

3. Supply Chain Decision Making Under the Stackelberg Game

3.1. Producers Misreporting Freshness

Without the application of blockchain technology and the existence of misrepresentation of freshness information, fresh produce producers may misrepresent the freshness of their products for the purpose of revenue maximization. Let the misrepresented freshness be a complete misrepresentation at $\theta(t_v) = 1 - \frac{(vt)^2}{T^2} 0 \leq t < T, 0 \leq v \leq 1$, $v = 0$. The misrepresented freshness is larger than the true freshness, and the seller's ignorance of the true freshness leads to an inflated order quantity of $D_{nv} = \theta(t_v)(\alpha - bp), 0 \leq t_v < t$ for the seller and $\theta(t)D$ for the producer at the actual freshness, at which point the profit functions of the produce producer and seller are:

$$\pi_{sv} = (\omega_v - c_1 - c_2)D_{nv} \tag{1}$$

$$\pi_{rv} = D_n(p_v - c_2) - \omega D_{nv} \tag{2}$$

The first-order derivative of equation (2), the extreme value of the verification of $\frac{\partial^2 \pi}{\partial {p_v}^2} = -2b\theta < 0$, prove that there is an extreme value. The optimal response function $p = \frac{bc_2\theta + \alpha\theta + b\theta_v\omega}{2b\theta}$ of the seller can be obtained by making $\frac{\partial \pi_{rv}}{\partial p_v} = 0$ and substituting it back into equation (1) to obtain

$$\omega_v = \frac{-bc_2\theta + \alpha\theta + b(c_1 + c_2)\theta_v}{2b\theta_v} \tag{3}$$

Substituting Eq. (3) back into the seller's optimal response function yields

$$p_v = \frac{bc_2\theta+3\alpha\theta+b(c_1+c_2)\theta_v}{4b\theta} \tag{4}$$

Substituting equations (3) and (4) back into equations (1) and (2), respectively, we obtain the profits of fresh produce producers and sellers in the case of freshness misreporting, respectively:

$$\pi_{sv} = \frac{(bc_2\theta-\alpha\theta+b(c_1+c_2)\theta_v)^2}{8b\theta} \tag{5}$$

$$\pi_{rv} = \frac{(bc_2\theta-\alpha\theta+b(c_1+c_2)\theta_v)^2}{16b\theta} \tag{6}$$

The total supply chain profit is

$$\pi_v = \frac{3(bc_2\theta-\alpha\theta+b(c_1+c_2)\theta_v)^2}{16b\theta} \tag{7}$$

$$D_v = -\frac{\theta_v(bc_2\theta-\alpha\theta+b(c_1+c_2)\theta_v)}{4\theta} \tag{8}$$

$$D = \frac{\left(\alpha\theta-b\left(c_1\theta_v+c_2(\theta+\theta_v)\right)\right)}{4} \tag{9}$$

Conclusion 1:The scenario of misrepresentation of freshness increases transaction costs and both producers and sellers increase pricing.

Proof: Find the first-order derivative of p_v and ω_v with respect to transaction costs c_2 : $\frac{\partial p_v}{\partial c_2} = \frac{\theta+\theta_v}{4\theta} > 0$, $\frac{\partial \omega_v}{\partial c_2} = \frac{-\theta+\theta_v}{2\theta_v} > 0$. It can be shown that both the selling price and the wholesale price increase with higher transaction costs, and the proof is complete.

$\frac{\partial \omega_v}{\partial v} = \frac{t^2(t-T)(t+T)v(bc_2-\alpha)}{b(T^2-t^2v^2)^2}$, since $t < T$,so when $c_2 > \frac{b}{\alpha}$, an increase in the level of misreporting leads to an increase in the wholesale price, $\frac{\partial P_v}{\partial v} = \frac{(c_1+c_2)t^2v}{2(t-T)(t+T)} < 0$,the sales price decreases when the level of misreporting increases.

When transaction costs increase in the case of misrepresentation of freshness, the transaction costs of supply chain members will have a negative impact on wholesale prices, market demand and supply chain members' profits. At the same time, if the market is flooded with fresh produce with low authenticity of freshness, consumer demand for fresh produce will also decrease, and due to the perishable nature of fresh produce, sellers will have to reduce the selling price to reduce their losses, which further affects the profit level of supply chain members, resulting in a vicious circle. Therefore, sellers of fresh produce have an incentive to circumvent freshness misrepresentation through the implementation of blockchain technology, thereby reducing transaction costs and the negative impact of consumer trust on demand and increasing profits

3.2. Adopting Blockchain

The application of blockchain can not only shorten the production time of fresh produce as $\hat{t}$, but also realize information sharing and save the transaction costs of supply chain members, while considering the one-time cost of applying blockchain. The whole life cycle information of fresh agricultural products can be completely and accurately recorded and stored in the product information traceability system supported by blockchain technology. Therefore, blockchain technology can circumvent the producer's freshness misrepresentation behavior, and consumers completely trust the freshness of the products. At this time, the freshness function is $\theta(\hat{t}) = 1 - \hat{t}^2/T^2, 0 < \hat{t} < t$ and the market demand is $D = \theta(\hat{t})(\alpha - bp_b + \beta g)$.

In decentralized decision-making, agricultural producers and sellers make decisions independently, with agricultural producers as leaders and sellers as followers. Producers of agricultural products decide the wholesale price of agricultural products with the focus on maximizing their own interests. The seller decides the level of blockchain technology application and market selling price. In this case, the supply chain is led by the producer, and the decision-making process is as follows: firstly, the level of blockchain technology application is determined, and then the producer and the seller determine the wholesale price and the selling price respectively. In the case of applying blockchain technology, the profit functions of agricultural producers and sellers are:

$$\hat{\pi}_s = (\omega_b - c_1)D_{bd} \tag{10}$$

$$\hat{\pi}_r = D_{bd}(p_b - \omega_b) - \frac{kg^2}{2} \tag{11}$$

According to the judgement theorem of the Hessian matrix negative definiteness, when $2kb\theta > \beta^2\theta^2$, the Hessian matrix is negatively defined, and it can be shown that there exists a unique optimal blockchain application level g and sales price p . The seller's optimal response function $p = \frac{k\alpha+bk\omega-\beta^2\theta\omega}{2bk-\beta^2\theta}$, $g = \frac{\beta\theta(-\alpha+b\omega)}{-2bk+\beta^2\theta}$ is obtained by associating $\frac{\partial \pi_r}{\partial p} = 0, \frac{\partial \pi_r}{\partial g} = 0$ and substituting back into equation (10) to obtain

$$\omega = \frac{\alpha+bc_1}{2b} \tag{12}$$

Substituting equation (12) back into the optimal reaction function yields

$$p = \frac{3bk\alpha-\alpha\beta^2\theta+b^2kc_1-b\beta^2\theta c_1}{4b^2k-2b\beta^2\theta} \tag{13}$$

$$g = \frac{\beta\theta(\alpha-bc_1)}{4bk-2\beta^2\theta} \tag{14}$$

Equations (12), (13), and (14) are substituted back into equations (10) and (11) to obtain the producer's and seller's profits, respectively:

$$\pi_s = \frac{k\theta(\alpha-bc_1)^2}{8bk-4\beta^2\theta} \tag{15}$$

$$\pi_r = \frac{k\theta(\alpha-bc_1)^2}{16bk-8\beta^2\theta} \tag{16}$$

The total supply chain profit is

$$\pi = \frac{3k\theta(\alpha - bc_1)^2}{16bk - 8\beta^2\theta} \quad (17)$$

Conclusion 2: When $0 \le c_1 \le c$, the profits of all members of the fresh produce supply chain increase after applying blockchain technology.

Proof: When $\beta^2\theta < 2bk$, $\frac{\partial^2 g}{\partial \beta^2} = \frac{\beta\theta^2(6bk+\beta^2\theta)(-\alpha+bc_1)}{(-2bk+\beta^2\theta)^3} > 0$, and $\frac{\partial g}{\partial \beta} = \frac{\theta(2bk+\beta^2\theta)(\alpha-bc_1)}{2(-2bk+\beta^2\theta)^2} > 0$, obtain proof.

It is known that consumers' preference for blockchain technology is positively correlated with the level of blockchain technology application. The optimal selling price of sellers after applying blockchain technology is inversely proportional to the level of blockchain application and application cost coefficient, and lie report influences the wholesale price of producers ω_v, while the wholesale price of producers $\hat{\omega}$ after applying blockchain technology is consistent with the wholesale price of freshness information symmetry ω.

Conclusion 3: Under decentralized decision-making, the producer's wholesale price is not related to the circulation time, while the seller's selling price is negatively related to the circulation time. However, sellers' profits are greater in the applied blockchain scenario than in the misrepresentation scenario.

Proof: $\frac{\partial p}{\partial \hat{t}} = \frac{k\hat{t}T^2\beta^2(-\alpha+bc_1)}{(2bkT^2+(\hat{t}-T)(\hat{t}+T)\beta^2)^2}$, $\alpha - bc_1 > 0$, $\frac{\partial p}{\partial \hat{t}} < 0$, get the conclusion 3, the proof of the end.

Conclusion 4 The seller's profit with blockchain applied is greater than the seller's profit in the misrepresentation scenario when $\frac{\sqrt{(-b+\alpha)\hat{t}^2+T^2(2b-\alpha+bc_1)}}{\sqrt{bt^2(1+c_1)}} \le v \le 1$.

Proof: When $0 \le v \le \frac{\sqrt{(-b+\alpha)\hat{t}^2+T^2(2b-\alpha+bc_1)}}{\sqrt{bt^2(1+c_1)}}$, $\hat{\pi}_s < \pi_{sv}$; when $\frac{\sqrt{(-b+\alpha)\hat{t}^2+T^2(2b-\alpha+bc_1)}}{\sqrt{bt^2(1+c_1)}} \le v \le 1$, $\hat{\pi}_s > \pi_{sv}$.

It can be seen that supply chain members each take their own profit maximization as their decision-making goal, and blockchain application costs reach a certain level will choose to reduce the application, affecting market demand and revenue. Whether sellers adopt blockchain technology or not depends on the level of misrepresentation and the range of transaction costs, and choosing to utilize blockchain technology under certain conditions can achieve the purpose of improving their own profits.

4. Numerical Analysis

In this section, through numerical simulation, we analyze the influence of relevant parameters on the equilibrium solution and the return of the supply chain system, and verify the relevant conclusions proposed in this paper.Let a secondary supply chain of fresh agricultural products, the production cost per unit of agricultural products is $c_1 = 2$, the sales price per unit of products is $p = 8$, the life cycle of fresh agricultural products is $T = 20$; the actual production time of agricultural products is $t = 4$, $\alpha = 100$, $b = 2$, $\beta = 0.5$.

As can be seen from Figure 2, as the production time of fresh produce increases, i.e., the freshness decreases, both producer profits and seller profits decrease. When the production time is low, the freshness of fresh produce is high, and the change in the level of misrepresentation at this time has little impact on the profits of supply chain members. As the production time increases, the impact of the level of misrepresentation on the profits of the supply chain members gradually increases, when $t = 15$, when the freshness of fresh produce further reduces, and the supply chain profits are also reduced. However, it can be seen that the closer the misrepresentation level is to 1 under the three production times, i.e., the more truthful the freshness information is, the higher the profits of the supply chain members are. And the increase in production time reduces the profit of the producer more than that of the seller, which shows that low freshness is more damaging to the profit of the producer.

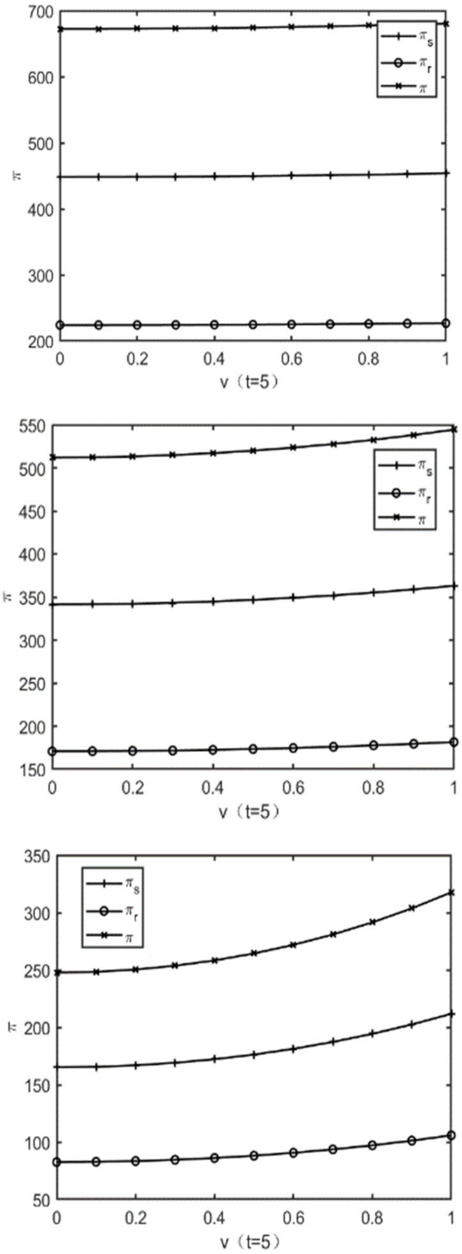

Figure 2. Impact of Misrepresentation Levels on Supply Chain Profitability at Different Freshness Levels

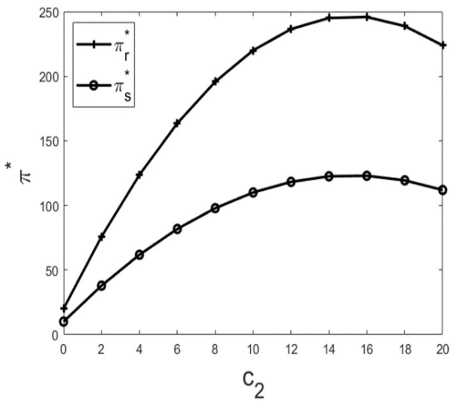

Figure 3. Impact of Transaction Costs on Supply Chain Members' Profits Before and After Applying Blockchain

π^* represents the profit difference between supply chain members applying blockchain technology and misrepresenting the situation, and it can be seen that if blockchain technology is utilized, the profit difference between the seller and the producer is positive, i.e., the profits of both the producer and the seller are enhanced. And when the transaction cost reaches a certain level, the profits of the supply chain members reach the highest value, the transaction cost continues to increase, and at this time, the enhancement effect of applying blockchain technology on the profits of the supply chain begins to diminish.

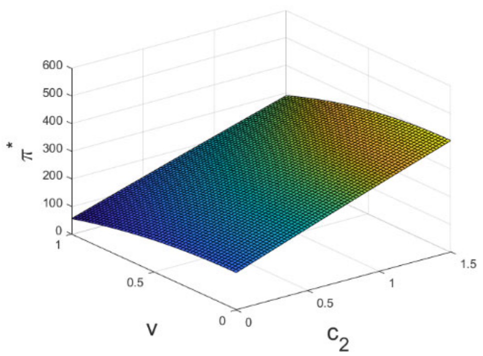

Figure 3. Supply Chain Profit Changes

From Figure 4-3, it can be seen that when the level of misrepresentation is low, the higher the transaction cost of fresh produce supply chain, the stronger the effect of blockchain technology on the total profit of supply chain. It can be seen that blockchain technology can effectively circumvent the effects of producers' freshness misreporting and transaction costs on supply chain profits, and the effect of reducing transaction costs is stronger than that of circumventing misreporting behaviors. Therefore, sellers can significantly improve their profits by applying blockchain technology when the level of misrepresentation is low and the transaction cost is high.

5. Literature References

In recent years, more and more scholars have begun to pay attention to the research on the supply chain of fresh agricultural products, and the current research directions related to this paper mainly include the research on supply chain application of blockchain technology, supply chain decision-making of fresh agricultural products, and application of blockchain technology to the supply chain of fresh products.

Among the studies related to the application of blockchain technology to supply chain systems, Pun et al [1] (2021) verified the effectiveness of blockchain technology to solve the problem of consumer purchase regret in a marketplace consisting of manufacturers and deceptive counterfeiters, and pointed out that blockchain should be used when the quality of counterfeit products and the trust of consumers are at what level, and advocated that the government should provide subsidies to encourage the use of blockchain technology. Zhao Huida et al [2] (2022) explored the question of whether the port and shipping supply chain is centralised and whether to invest in a portfolio strategy from the technical characteristics of blockchain decentralisation.Zhang et al [3] (2022) constructed a retailer competition model for initial and entry retailers. It is found that consumer privacy concerns reduce consumers' valuation of products, and therefore retailers' prices and profits decrease when adopting blockchain technology. The two retailers only apply blockchain when consumer privacy concerns are low and information transparency promotions are high.Xu and He [4] (2023) investigated the decision of retail platforms to proactively disclose product quality information using blockchain technology. The study pointed out that regardless of the disclosure strategy, consumers' deliberation and purchasing decisions depend on the cost of deliberation and the product price, identifying the conditions under which retail platforms should disclose high-quality information in the face of varying disclosure costs.Wu and Yu [5] investigated the impact of blockchain technology on agency sales and resale platform providers from the perspective of information transparency and transaction costs. Blockchain technology can eliminate information asymmetry and transaction costs. The optimal strategy of the platform strongly depends on the transaction cost, commission rate, and the operating cost of the blockchain.Zhao and Li [6] investigated the adoption strategy of blockchain traceability system for a dual-channel supply chain of perishable goods under differential pricing and nondifferential pricing policies, which mainly depends on its derogation effect, premium effect, production cost, and labelling cost.

In the decision-making study of fresh produce supply chain, Zhao Zhong and Cheng Yu [7] considered the quality loss and quantity loss of fresh produce and analysed the impact of preservation efforts, option price and execution price on supply chain decision-making and coordination effect in a two-level fresh produce supply chain. Tang Run et al [8] considered the impact of time and temperature factors on the quality of fresh food, and investigated the hybrid channel coordination problem of a two-tier fresh food supply chain under the coexistence of traditional sales channels and online direct sales channels. Wang Wenlong et al [9] (2023) constructed a differential game model to study the dynamic joint decision-making of a dual-channel supply chain for fresh produce from a dynamic perspective in the time dimension. Liu Molin et al [10] (2020) targeted fresh food suppliers and fresh food e-commerce supply chains that provide value-added services. The study analysed the impact of freshness elasticity of demand, service elasticity of demand and other factors on optimal decision-making, and pointed out the relationship between the implementation of the "high quality and low price" and "high quality and good price" strategies and the level of freshness elasticity of demand and service elasticity of demand. Tang Yuewu et al [11] (2018) constructed a single-stage and two-stage pricing and inventory decision model for retailers based on the newsboy model, taking into account the strategic behaviour of consumers. The study analysed the mechanism of product value residual rate on consumer behaviour, retailers' optimal pricing, optimal inventory level and retailers' profit.

In a study related to the application of blockchain technology to fresh produce supply chains, Wu et al [12] investigated the strategies for adopting blockchain technology in a three-level fresh produce supply chain that includes a third-party logistics service provider. The study pointed out that the adoption of blockchain technology is not necessarily an optimal decision for fresh produce supply chains, which is related to the consumer acceptance of products without blockchain technology, the deterioration rate of fresh produce, and the proportion of traceability costs allocated to the supply chain members when blockchain technology is adopted.Zhao et al [12] investigated the application of differential pricing and nondifferential pricing policies under two policies in dual-channel perishable goods supply chains blockchain traceability technology adoption strategies. It is pointed out that the adoption decision mainly depends on its derogation effect, premium effect, production cost and labelling cost. Liu Liang et al [13] studied the variation of equilibrium solutions under different application scenarios in a secondary fresh food supply chain from the perspective of blockchain suppression of misreporting problem, and sought the cost investment threshold of blockchain technology under different scenarios. The study points out that whether to invest in blockchain depends on the supplier. Yang Ya et al [14] investigated the optimal decision-making in secondary fresh food supply chain using a single-cycle newsboy model under the perspective of freshness information asymmetry. Qingkai Ji et al [15] study the on-chaining decisions of suppliers in a supply chain of two suppliers and a retailer that has built a blockchain traceability platform. The study shows that it is not necessarily beneficial for supply chain members to be "on-chained", depending on the production cost of the product, the degree of brand differentiation, and the impact of blockchain on consumers' product valuation. Liang Xi et al [16] compared and analysed the pricing and channel selection strategies of a dual-channel supply chain under different scenarios, and derived the thresholds for the degree of blockchain usage and order quantity fluctuations to positively affect profits by introducing parameters such as transaction costs. Zhang [17] (2023) investigated strategies under three blockchain adoption scenarios in a dual-channel supply chain, and concluded that the blockchain adoption strategies of supply chain members depend on unit blockchain operating costs, direct marketing costs, and demand fluctuations. Wu et al [12] (2023) investigated blockchain technology adoption strategies in a fresh produce supply chain consisting of suppliers, third-party logistics service providers and e-retailers. By analysing the optimal strategies of the supply chain members in three scenarios, the study points out that the adoption of blockchain technology is not necessarily an optimal decision for the supply chain, which is related to the consumer acceptance of products without blockchain technology, the deterioration rate of the fresh products, and the proportion of the traceability costs allocated.

It can be seen that in the above research, the research of fresh produce supply chain is involved in the ordering strategy, loss control and the corresponding impact of freshness. And combined with the characteristics of supply chain contractual coordination management, the corresponding coordination analysis has been carried out, with relatively good coordination effect. At the same time, the effects of physical and value loss of fresh produce on supply chain coordination are also considered. The main research on fresh produce supply chain currently focuses on aspects characterising freshness change such as preservation technology, inventory demand, spoilage rate, etc., while there are fewer studies on member decision-making triggered by member misreporting behaviour in supply chain management.

In summary, most of the studies that have used blockchain technology features to solve problems related to fresh produce supply chains have analysed different supply chain structures and different perspectives on the application of blockchain technology for decision making. Few studies have combined blockchain technology with the freshness misrepresentation problem in fresh produce supply chains to explore how supply chain members make decisions under different levels of misrepresentation. The most relevant literature to this paper is [6, 12-14], but literature [6] studies the investment decision problem of blockchain technology under differential and non-differential pricing in a two-channel supply chain, and literature [12] studies the blockchain investment decision under different dominant player scenarios in a three-tier supply chain. They all study from the perspective of blockchain affecting transaction cost or freshness and do not introduce the relationship between blockchain technology and misrepresentation. Literature [13] further investigates the supply chain decision problem of applying blockchain to solve the misreporting problem based on literature [14], and coordinates it through repurchase compensation contract and revenue sharing contract, but both of them study the quantity demanded as a stochastic demand function about freshness, and do not take into account the effect of price changes.

This paper starts from the realistic background of fresh produce development and freshness misrepresentation problem in China. Based on the above literature, this paper investigates whether fresh produce supply chains facing the problem of misreporting should adopt blockchain technology, and what factors influence the decision to adopt blockchain technology, and how supply chain members make decisions on pricing and the level of blockchain application. The study aims to provide managerial insights into supply chain decisions to apply blockchain technology. For a two-tier fresh produce supply chain consisting of a fresh produce producer and a seller, we first analyse the optimal pricing decisions and profits of the fresh produce supply chain members under the scenario of the producer misrepresenting the freshness, and then analyse the optimal pricing decisions and blockchain adoption levels of the supply chain members as well as their profits under the scenario of the seller adopting blockchain technology. By comparing the profits of supply chain members in the two scenarios, we identify the factors that affect the level of blockchain adoption and the conditions for blockchain adoption.

The main contributions of this paper are: analysing the specific conditions for the adoption of blockchain technology in fresh produce supply chains, considering the impact of consumer traceability preferences on the decision to apply blockchain technology, and analysing the changes in supply chain profitability under different levels of misreporting by producers, which enriches the existing research results.

This paper studies a secondary fresh produce supply chain consisting of a fresh produce producer and a seller, where the producer supplies fresh produce to the seller. Due to the private nature of freshness of fresh produce, the producer may misrepresent the freshness in the case of asymmetric freshness information.

6. Conclusion

Fresh produce market information asymmetry and freshness misrepresentation behaviors affect the true freshness information of fresh produce, leading to a reduction in the overall stability of the supply chain. The application of blockchain technology provides a channel for consumers to verify the true freshness of fresh produce, and also helps sellers to avoid freshness misrepresentation by produce producers and reduce transaction costs. Therefore, in order to study the strategy of applying blockchain technology in the fresh produce supply chain, this paper considers a secondary supply chain consisting of fresh produce producers and sellers. The optimal pricing and blockchain application level decisions of the supply chain members under two scenarios, a supply chain where producers misrepresent freshness information and the application of blockchain technology, are analyzed. by comparing the optimal decisions in the two scenarios, we identify the specific conditions for the adoption of blockchain technology, and also demonstrate that the level of blockchain technology adoption is related to parameters such as consumer traceability preferences and blockchain cost coefficients. The above study shows that (1) the level of producer freshness misrepresentation increases and producers increase wholesale prices with it, while the opposite is true for sellers. (2) Supply chain transaction costs increase and both producers and sellers increase pricing. (3) When the production cost and the cost coefficient of blockchain application as well as the level of misrepresentation satisfy certain conditions, the profit in the case of applying blockchain technology is higher than that in the case of misrepresentation, and then the seller should choose to apply blockchain technology. (4) Under decentralized decision-making, the producer's wholesale price is independent of the circulation time, while the seller's sales price is negatively correlated with the circulation time.

Finally, this paper has investigated fresh produce supply chains under misrepresentation of producer freshness information . Further research can be conducted by considering the decision-making mechanism of fresh produce supply chain under the joint effect of other information asymmetries such as cost information, taking into account the misrepresentation by sellers or bilateral misrepresentation.

References

[1] Pun, H., Swaminathan, J.M., Hou, P., 2021. Blockchain Adoption for Combating Deceptive Counterfeits. Prod Oper Manag 30, 864–882. https://doi.org/10.1111/poms.13348

[2] Azadi Z,Eksioglu S D, Eksioglu B, et al. Stochastic optimization models for joint pricing and inventory replenishment of perishable products [J]. Computers & Industrial Enginecring, 2019,127: 625-642.

[3] Jansscn L,Sauer J,Claus T,et al. Development and simulation analysis of a new perishable inventory model with a closing days constraint under non-stationarystochastic demand[J]. Computers & Industrial Engineering,2018,118: 9-22.

[4] Pauls-Worm K G J, Hendrix E M T,Alcoba A G, et al.Order quantities for perishable inventory control with non-stationary demand and a fill rate constraint[J]. InternationalJournal of Production Economics, 2016,181: 238-246.

[5] Sebatjane M,Adetunji O. A three-echelon supply chain for economic growing quantity model with price and freshness-dependent demand: Pricing, ordering and shipmentdecisions [J]. Operations Research Perspectives, 2020,7: 1-15.

[6] Ma X,Wang S, Islam S M, et al.Coordinating a three-echelon fresh agricultural products supply chain considering freshness-keeping effort with asymmetricinformation[J].Applied Mathematical Modelling, 2019,67:337-356

[7] Burer S,Jones P.C.,Lowe T.J.Coordinating the supply chain in the agricultural seed industry[J]. European Journal of Operational Research, 2008,185(1): 354-377.

[8] Jang W., Klein C.M.Supply chain models for small agricultural enterprises[J].Annals of operations research, 2011, 190(1): 359-374.

[9] Cai X., Chen J.,Xiao Y., et al. Optimization and Coordination of Fresh Product Supply Chains with Freshness Keeping Effort[J]. Production and Operations Management,2010,19(3): 261-278.

[10] Kazaz B. , Webster S. The Impact of Yield-Dependent Trading Costs on Pricing and Production Planning Under Supply Uncertainty [J]. Manufacturing & Service Operations Management, 2011,13(3): 404-417

[11] Helo P,Hao Y. Blockchains in operations and supply chains: A model and reference implementation[J]. Computers & Industrial Engineering, 2019,136:242-251.

[12] Allen D WE, Berg C, Davidson S, et al. International policy coordination for blockchain supplychains[J].Asia & the Pacific Policy Studies, 2019,6(3):367-380.

[13] Tnnissen S, Teuteberg F.Analysing the impact of blockchain-technology for operations and supply chain management: An explanatory model drawn from multiple case studies[J]. InternationalJournal of Information Management, 2020, 52: 101953.

[14] Fan Zhiping, Wu Xueyan , Cao Bingbing.Considering the traceability awareness of consumers:should the supply chain adopt the blockchain technology?[J].Annals of Operations Research, 2020:

[15] Liu Pan, Long Yue, Song Haicao, et al. Investment decision and coordination of greenagri-food supply chain considering information service based on blockchain and big data[J]. Journal ofCleaner Production, 2020,277: 123646.

[16] Xu Xiaoping,Zang Mengying, Dou Guowei, et al.Coordination of a supply chain with an online platform considering green technology in the blockchain era[J]. International Journal of ProductionResearch, 2021: 1-18.

[17] Zhang, P., Y. He, and C. Shi. 2017. “Retailer’s Channel Structure Choice: Online Channel, Offline Channel, or Dual Channels .” International Journal ofProduction Economics 191:37–50.