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Research on Pricing and Coordination of Fresh Supply Chain with Altruistic Fairness Concern

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Abstract: *Considering a fresh supply chain consisting of one supplier and one retailer, this paper studies the pricing and coordination of fresh supply chain under altruistic fairness concern of the supplier. Based on the centralized decision and Stackelberg game theory, the decentralized decision model of supplier's altruistic fairness concern is constructed, the pricing decision is analyzed, and the cost-sharing contract based on altruistic fairness concern is designed for coordination. The results show that the altruistic fairness concern of supplier can inspire retailer to improve the freshness-keeping effort level, which can help to the operation of retailer and supply chain, but damage the profit of himself. Freshness-keeping efficiency has an important impact on the marketing strategy of retailer: the retailer will implement the "high-quality with high price" if the freshness-keeping efficiency is low, otherwise implement the "high-quality with low price". Cost-sharing contract based on the altruistic fairness concern can realize the perfect coordination of supply chain within a certain range.*

Keywords: *fresh agricultural produce; altruistic fairness concern; pricing decisions; supply chain coordination*

1. Introduction

Owing to the immature fresh-keeping technology and the easily rotten characteristics of fresh agricultural products, the consumption rate of fresh agricultural products in China is as high as 30%[1]. The high loss rate causes retailers to invest more preservation costs in distribution, further widening the profit gap with suppliers, which is not conducive to long-term cooperation of supply chain members. For example, Aixianfeng has fallen into a dilemma due to the high cost of fresh-keeping and distribution, while Zespri, the leading brand of kiwi fruit market, further benefits JD Fresh on the basis of ensuring its own profits, and provides financial support for JD to promote win-win cooperation[2]. Consequently, the government has also published some policies to motivate stable development between enterprises. For example, it is proposed to further optimize the development environment in the circulation field and rectify the industrial order[3]. Therefore, it's important for fresh supply chain management to explore the optimal decisions under the supplier's altruistic fairness concern, and how to improve the performance of supply chain.

In recent years, many scholars have paid high attention to the pricing and coordination of the fresh supply chain. Liu M L et al[4] discussed the optimal decision of the fresh supplier responsible for the preservation efforts under the centralized and decentralized decision-making, and designed a "revenue sharing-two-way cost sharing" contract for coordination. Cao Y et al[5] based on the consumer utility theory, and investigated the pricing decision of retailers. Yang L et al[6] discussed the fresh-keeping efforts and pricing strategies under different sales models based on the retail model, dual-channel model and O2O model. Zheng Q et al[7] designed cost-sharing contracts and revenue-sharing contracts to coordinate when considering retailers' efforts to keep fresh, and compared the coordination effects of the two contracts. Nevertheless, the above studies are based on the assumption of rational people, and the enterprise's attention to profit distribution isn't contained.

Behavioral economics found that in decision-making, enterprises not only pay attention to their own profits, but also pay attention to the profit distribution of themselves and their cooperative partners[8]. If the income of the enterprise is far less than that of the cooperative enterprise, there will be adverse equity concerns, and then measures will be taken to punish the cooperative enterprise; On the contrary, there will be concerns about the benefits of equity, and actions will be taken to benefit the cooperative enterprises[9]. Some scholars have studied the impact of equity concerns on the fresh supply chain. Zhang Q et al[10] analyzed the impact of equity concerns of different members on pricing decisions. Sun Y L et

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al[11] studied the impact of fairness concern of different members on supply chain coordination under the revenue-sharing contract. Based on this, some scholars added the impact of the freshness-keeping effort level on the supply chain. Zhang X et al[1] took into account the impact of retailers' efforts to keep fresh on freshness, and designed an improved side-payment self-execution contract to coordinate. Pu X J et al[12] introduced the reference point effect, compared and analyzed the production quality level under the current reference point and the non-current reference point, and discussed the impact of farmers' equity concerns on the supply chain. However, the above research on fairness concerns is that the supply chain members are dissatisfied with the part of the profits less than that of the cooperative enterprises, and then produce jealousy, which is reflected in the decision-making in the form of fairness concerns. This is the irrational behavior with self-interest for members to ensure their own profits on the supply chain.

However, in the fresh supply chain, the altruistic fairness concern of the supplier as the leading enterprise stem from the sympathetic and negative utility generated when the decision-maker's income is higher than that of the cooperative enterprise, which urges the decision-maker to make further concessions to the cooperative enterprise and maintain the stable development of the supply chain on the basis of ensuring his own income[13]. Unlike the negative equity concern, which emphasizes that decision-makers tend to reduce the profit gap with cooperative enterprises, the altruistic fairness concern focuses on maintaining the cooperative relationship between supply chain members. At present, the research on the altruistic fairness concern is mainly concentrated in the field of industrial supply chain, only a few scholars introduced it into the fresh supply chain, and mainly concentrated on pricing and coordination. Feng C et al[14] investigated the pricing decision in the disadvantageous and altruistic fairness concern, and analyzed the impact of the fairness concern of different members on the supply chain. Liu L et al[15]studied the impact of equity concerns on the ordering price and effort level of agricultural products in the "enterprise-farmer" supply chain. Yu D D et al[16] considered the impact of the favorable and unfavorable unfairness of cooperatives on the output of agricultural products when the sales cost information is asymmetric, and discussed the effect of wholesale price contracts on supply chain coordination. Further, Pu X J et al[17]studied from a dynamic perspective by constructing an evolutionary game model to explore the impact of adverse and beneficial inequities of farmers on product quality.

To sum up, the previous studies on fresh supply chain mainly have two deficiencies. Firstly, most of them are based on the assumption of rational people, but only a few scholars introduce the altruistic fairness concern into the fresh supply chain, but don't consider the easily rotten characteristics of fresh agricultural products. Secondly, although relevant research shows that the concerns of altruistic fairness concern can promote coordination, there are few contracts based on the concerns of altruistic fairness concern. For this reason, this paper studies a fresh supply chain consisting of one supplier and one retailer. Based on the centralized decision, a decentralized decision model of supplier's altruistic fairness concern is constructed to analyze the impact of supplier's profit-sharing behavior on supply chain pricing and profits. Furthermore, this paper proposes a cost-sharing contract based on the concern of equity of profit distribution, which provides a reference for fresh supply chain management.

2. Model description

We consider a supplier-led fresh supply chain consisting of one supplier and one retailer. The supplier is responsible for the processing and packaging of fresh agricultural products, and its unit cost is c. The retailer transport fresh agricultural products from supplier to the retail market. In the process, it's necessary to use fresh-keeping equipment. For the convenience of analysis, the following assumptions are made.

Assumption 1. Based on the research of Zhang Q et al[18], in the sales cycle T, the freshness of fresh agricultural products decreases with time ($\theta'(t) < 0$, $\theta''(t) < 0$), it can be described as $\theta(t) = \theta_0 + ke - \eta_0(t/T)^2$.

Assumption 2. The market demand for fresh agricultural products is affected by the retail price and freshness. According to the research of Zheng Q et al[19], the market demand can be expressed as $q = \alpha - \beta p + \lambda\theta(t)$.

Assumption 3. Due to the perishable characteristics of fresh agricultural products, retailer need invest in fresh-keeping efforts, and the marginal fresh-keeping cost is strictly increasing[20]. Therefore, the fresh-keeping cost can be expressed as $c(e) = 1/2\,\mu e^2$.

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The interpretation of symbols in the model is shown in Table 1.

Table 1: Notations

Symbol	Interpretation
α	potential market size
β	consumer price sensitivity coefficient
λ	sensitivity coefficient of consumer freshness
c	unit production cost
p	retail price of fresh agricultural products
q	market demand
$\theta(t)$	freshness of fresh agricultural product
θ_0	initial freshness of fresh agricultural products, $\theta_0 \in (0,1)$
k	influence coefficient of freshness-keeping technology on fresh-keeping effect, $k \in (0,1-\theta_0)$
e	freshness-keeping effort level, $e \geq 0$
η_0	extreme attenuation of fresh agricultural products after the sales cycle T, $\eta_0 \in (0,1)$
t	Circulation time of fresh agricultural product, $t \in [0,T]$
T	sales cycle
μ	influence coefficient of freshness-keeping effort level on cost

3. Model construction and analysis

3.1 Centralized decision

Considering system profit maximization, supplier and retailer jointly determine the retail price p and the freshness-keeping effort level e. The market demand for fresh agricultural product is equal to the sales volume of a sales cycle T, regardless of the sales surplus and shortage replenishment, the market demand for fresh agricultural product is equal to the sales volume of a sales cycle T, it can be expressed as:

$$q = \int_0^T (\alpha - \beta p + \lambda(\theta_0 + ke - \frac{\eta_0 t^2}{T^2}))dt = (\alpha - \beta p + \lambda(ke + \theta_0 - \frac{\eta_0}{3}))T \tag{1}$$

The supply chain profit is:

$$\pi_{sc}^c = (p-c)q - \frac{\mu e^2}{2} \tag{2}$$

To maximize π_{sc}^c, we verify the joint concavity of π_{sc}^c with respect to e and p, and solve the optimization problem (2) to obtain the optimal decisions are as follows:

$$e^{c*} = \frac{k\lambda T(-3\beta c - \lambda\eta_0 + 3\lambda\theta_0 + 3\alpha)}{3(2\beta\mu - \lambda^2 k^2 T)} \tag{3}$$

$$p^{c*} = \frac{((\eta_0 - 3\theta_0)\lambda - 3\beta c - 3\alpha)\mu + 3Tck^2\lambda^2}{3\lambda^2 k^2 T - 6\beta\mu} \tag{4}$$

3.2 Supplier altruistic fairness concern decentralized decision

According to the F-S model proposed by Ernst[9], the supplier's utility function is:

$$U_s^l = \pi_s^l - \eta \cdot \max[(\tau \cdot \pi_r^l - \pi_s^l), 0] - \theta \cdot \max[(\pi_s^l - \tau \cdot \pi_r^l), 0] \tag{5}$$

Where η is negative fairness concern coefficient, θ is altruistic fairness concern coefficient. Take the retailer's profit as the supplier's profit reference point ($\tau = 1$). In this paper, The profit of supplier is greater than that of retailer, therefore, only the sympathetic negative utility of supplier is considered. The

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supplier's utility function is:

$$\begin{cases} \max\limits_{w} U_s^l = \pi_s^l - \theta \cdot (\pi_s^l - \pi_r^l) \\ s.t.\ \pi_s^l \geq \pi_r^l \end{cases} \tag{6}$$

The retailer is fair and neutral, and its decision function is equal to profit function:

$$\pi_r^l = (p - w)q - \frac{\mu e^2}{2} \tag{7}$$

According to the Stackelberg game, the optimal decisions of fresh supply chain are:

$$w^{l*} = \frac{3\beta c\theta - 2\lambda\theta\eta_0 + 6\lambda\theta\theta_0 + 6\alpha\theta - 3\beta c + \lambda\eta_0 - 3\lambda\theta_0 - 3\alpha}{9\beta\theta - 6\beta} \tag{8}$$

$$p^{l*} = \frac{((-3\theta_0 + \eta_0)\lambda - 3\beta c - 3\alpha)(1 - 2\theta)}{9\beta\theta - 6\beta} + \frac{(-3\beta c - \lambda\eta_0 + 3\lambda\theta_0 + 3\alpha)\mu(-1 + \theta)}{3(-\lambda^2 k^2 T + 2\beta\mu)(3\theta - 2)} \tag{9}$$

$$e^{l*} = \frac{(-1 + \theta)k\lambda(-3\beta c - \lambda\eta_0 + 3\lambda\theta_0 + 3\alpha)T}{3(3\theta - 2)(2\beta\mu - \lambda^2 k^2 T)} \tag{10}$$

$$\pi_s^{l*} = \frac{(-1 + \theta)(2\theta - 1)T\mu(-3\beta c - \lambda\eta_0 + 3\lambda\theta_0 + 3\alpha)^2}{9(3\theta - 2)^2(2\beta\mu - \lambda^2 k^2 T)} \tag{11}$$

$$\pi_o^{l*} = \frac{\mu(-1 + \theta)^2(-3\beta c - \lambda\eta_0 + 3\lambda\theta_0 + 3\alpha)^2 T}{18(3\theta - 2)^2(2\beta\mu - \lambda^2 k^2 T)} \tag{12}$$

$$\pi_{sc}^{l*} = \frac{(-1 + \theta)(5\theta - 3)T\mu(-3\beta c - \lambda\eta_0 + 3\lambda\theta_0 + 3\alpha)^2}{18(3\theta - 2)^2(2\beta\mu - \lambda^2 k^2 T)} \tag{13}$$

3.3 Model analysis

A parameter $\varphi = \lambda^2 / \mu$ is introduced in order to facilitate the analysis. It represents the ratio of market expansion effect and cost increase effect brought by improving the level of freshness-keeping efforts, which is called freshness-keeping efficiency. The larger φ, the higher the freshness-keeping efficiency.

Proposition 1 When $\varphi < \frac{\beta}{k^2 T}$, $p^{c*} < p^{l*}$; when $\frac{\beta}{k^2 T} < \varphi < \frac{2\beta}{k^2 T}$, $p^{c*} > p^{l*}$.

Proposition 1 indicates that when φ is low, the retail price under decentralized decision is higher than centralized decision. Because the cost increase effect is dominant, retailer will make price increases deviating from centralized decisions to ensure profitability. When φ is high, the retail price under decentralized decision is lower than centralized decision. Because of the strong effect of market expansion, retailer will make price reductions that deviate from centralized decisions to attract consumers.

Proposition 2 $\frac{\partial w^{l*}}{\partial \theta} < 0$, $\frac{\partial e^{l*}}{\partial \theta} > 0$.

Proposition 2 indicates that wholesale price of supplier increase with the altruistic fairness concern coefficient, and the level of freshness-keeping effort of retailer decrease with the altruistic fairness concern coefficient. This means that in order to improve the profitability of retailer, supplier can reduce wholesale price, and motivate retailer to invest efforts largely.

Proposition 3 $\frac{\partial \pi_r^{l*}}{\partial \theta} > 0$, $\frac{\partial \pi_{sc}^{l*}}{\partial \theta} > 0$, $\frac{\partial \pi_s^{l*}}{\partial \theta} < 0$.

Proposition 3 indicates that the profits of retailer and fresh supply chain are increases with altruistic fairness concern coefficient, the profit of supplier is decrease with altruistic fairness concern coefficient. This means that the profit-sharing behavior of supplier can increase the profits of retailer and fresh supply chain, but damage himself. Therefore, only when the government restrains or improves its public image, the supplier will consider transferring profits.

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In order to more clearly analyze the impact of supplier's profit-sharing behavior on supply chain profit, the supply chain efficiency is defined as the ratio of decentralized decision profit to centralized decision profit, that is $\eta = \partial\pi_{sc}^{l*} / \partial\pi_{sc}^{c*} = (5\theta - 3)(\theta - 1)/(3\theta - 2)^2$. η is positively correlated with θ, and the supply chain efficiency is 88.9% when θ is maximum. This shows that the supplier's profit-sharing behavior can slow down but can't completely eliminate the double marginal effect. Therefore, it's necessary to design contract for coordination.

4. Cost-sharing contract based on the altruistic fairness concern

In order to encourage retailer to invest in freshness-keeping efforts, a cost-sharing contract is designed. Supplier share ξ proportion of the freshness-keeping cost, while retailer share $1-\xi$ proportion of the freshness-keeping cost. At the same time, considering the role of θ in improving supply chain profits, it can be used as an endogenous variable to design a cost-sharing contract. From section 3, the value range of θ is $0 < \theta \le 1/3$. Therefore, set θ in the contract to $1/3$ to promote coordination.

The supplier's profit function is:

$$\pi_s^{cs} = (\rho p + w - c)q - \xi\frac{\mu e^2}{2} \tag{14}$$

The retailer's profit function is:

$$\pi_r^{cs} = ((1-\rho)p - w)q - (1-\xi)\frac{\mu e^2}{2} \tag{15}$$

The supplier's utility function is:

$$U_s^{cs} = \frac{2}{3}\pi_s^{cs} + \frac{1}{3}\pi_r^{cs} \tag{16}$$

In order to achieve coordination, the equilibrium solution under the contract should be equal to the centralized decision. Finally, we can get the conditions that the parameters meet when the two sides achieve perfect coordination.

Proposition 4 If the share ratio of freshness-keeping cost and wholesale price (ξ, w) is satisfied with $\xi = \frac{3(w^{cs} - c)(2\beta\mu - \lambda^2 k^2 T)}{\mu(3\alpha - 3\beta c - \lambda\eta_0 + 3\lambda\theta_0)}$ and $w_{\min} \le w^{cs} \le w_{\max}$, the fresh supply chain can obtain perfect coordination. of them, $w_{\min} = \frac{((3\theta_0 - \eta_0)\lambda + 9\beta c + 3\alpha)\mu - 6Tck^2\lambda^2}{6(2\beta\mu - \lambda^2 k^2 T)}$, $w_{\max} = \frac{\mu(5c\beta + \lambda\eta_0 - 3\lambda\theta_0 - 3\alpha) - 4Tck^2\lambda^2}{4(2\beta\mu - \lambda^2 k^2 T)}$.

According to $\partial\xi/\partial w^{cs} > 0$, we can obtain that the cost sharing ratio of supplier increase with the wholesale price. The increase of wholesale price strengthens supplier's profitability and made him have the ability to bear the cost of fresh-keeping to balance the profit distribution. Substitute $w_{\min}$ and $w_{\max}$ into the expression of ξ respectively, we can obtain that $1/2 \le \xi \le 3/4$. This means that the supplier bears more than half of the freshness-keeping costs.

After the contract, the unit profit of the supplier is $\delta^{cs} = p^{cs} - w^{cs}$. It can be obtained $\delta^{cs} > \delta^{l}$. This means that although the supplier bears more than half of the freshness-keeping costs, it can be compensated by obtaining higher unit profits than before coordination. Therefore, the contract can coordinate the fresh supply chain and achieve win-win cooperation.

5. Numerical analysis

Numerical analyses are introduced in this section to further reveal the impact of system parameters. According to the research of Zhang Q et al[10], the parameters as follows: $\alpha = 110, \beta = 20, T = 8, \eta_0 = 0.5, \theta_0 = 0.7, \mathrm{k} = 0.25$.

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Firstly, analyze the impact of the altruistic fairness concern coefficient on supplier profit, retailer profit and supply chain profit, as shown in Figure 1. retailer's profit and the supply chain's profit increases with the increase of altruistic fairness concern coefficient, while the supplier's profit decrease. This shows that the profit-sharing behavior of supplier can improve the profits of retailer and supply chain obviously. Therefore, supplier can help retailer increase profits and achieve win-win cooperation by sacrificing a small part of profits. This also further explains that it is reasonable to set the altruistic fairness concern coefficient as $1/3$ in the contract.

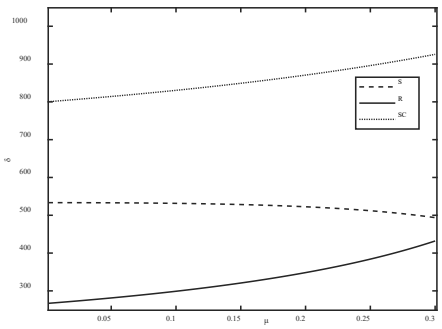

Figure 1: Effect of θ on profit

Secondly, analyze the impact of system parameters on supplier's unit profit after contract implementation, as shown in Figure 2 and Figure 3. As can be seen from Figure 2, when λ increases, the unit profit of supplier increases rapidly. Because λ larger means higher freshness-keeping efficiency, the market expansion effect brought by improving the level of freshness-keeping efforts is more obvious, and the supplier's profit-sharing behavior can promote their own profits. Similarly, as can be seen from Figure 3, when μ is small, the supplier can obtain higher unit profit. This indicates that supplier should choose strong retailer, because such retailer have higher fresh-keeping efficiency, which is conducive to increasing supplier profits and achieving win-win cooperation.

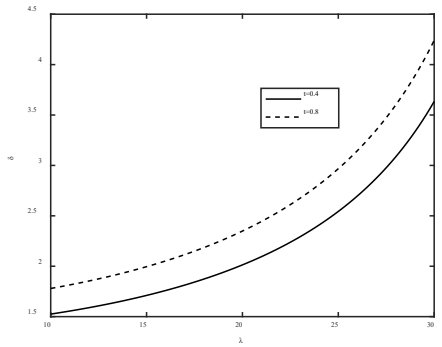

Figure 2: Effect of λ on supplier unit profit

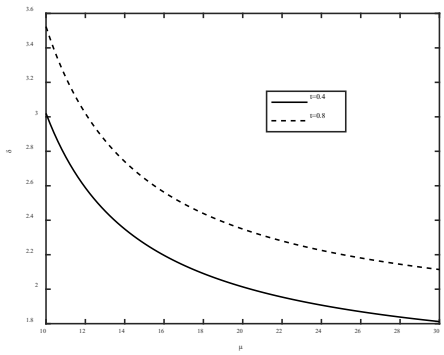

Figure 3: Effect of μ on supplier unit profit

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6. Conclusion

This paper takes the fresh supply chain as the research object, establishes the centralized decision and centralized decision models, analyzes the pricing of the fresh supply chain under the altruistic fairness concern, and designs the cost-sharing contract based on the altruistic fairness concern to coordinate. The research shows that the profit-sharing behavior of supplier can improve the level of retailer's freshness-keeping, which is beneficial to the operation of retailer and fresh supply chain, but will hurt himself. Retailer's freshness-keeping efficiency has an important impact on the pricing decision of the supply chain. If the freshness-keeping efficiency is low, retailer will increase the retail price. On the contrary, retail will reduce the retail price. Within a certain range, the cost-sharing contract based on the altruistic fairness concern can achieve the perfect coordination of the supply chain, in which the supplier bears more than half of the preservation costs, but can be compensated by obtaining higher unit profits.

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