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Operational Decisions in a Fresh Agricultural Products Supply Chain under Production-Logistics Collaboration

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Abstract: Fresh agricultural product supply chains face significant challenges in coordinating freshness preservation and logistics operations. To examine the value of production-logistics collaboration, this paper develops a three-tier supply chain system consisting of a supplier, a retailer, and a logistics service provider. The optimal decisions and profit outcomes under decentralized operation and production-logistics collaboration are compared within a Stackelberg game framework. The optimal wholesale price, purchase quantity, freshness preservation effort level, and member profits are derived under both modes. The results show that higher demand price sensitivity reduces the optimal purchase quantity and freshness preservation effort level, while a stronger price impact of freshness preservation effort encourages supply chain members to expand purchase scale and increase preservation investment. Compared with decentralized operation, production-logistics collaboration improves the optimal purchase quantity, the retailer's profit, and the joint profit of the supplier and the logistics service provider. With an appropriate profit-sharing mechanism, collaboration enables mutual benefit between the supplier and the logistics service provider. Numerical analysis further indicates that this collaboration mode is more suitable for fresh agricultural products with low demand price sensitivity and strong freshness value conversion capability.

Keywords: Fresh Agricultural Products Supply Chain; Production-logistics Collaboration; Stackelberg Game; Freshness Preservation Effort.

1. Introduction

Fresh agricultural products are characterized by perishability, short shelf life, and high circulation loss. Their market value depends not only on product supply itself, but also on cold-chain distribution, terminal sales, and the level of logistics services. With the rapid development of cold-chain logistics, instant retailing, and fresh product e-commerce, consumers have increasingly high requirements for product freshness, delivery timeliness, and quality stability. Consequently, operational management in fresh agricultural products supply chains has become an important topic in supply chain management research.

Existing studies on operational decisions in fresh agricultural products supply chains mainly focus on pricing decisions, loss control, and supply chain coordination. Yu and Xiao[1] incorporated a third-party logistics service provider into a fresh agricultural products supply chain and examined cold-chain service level and pricing decisions. Mohammadi et al.[2] studied supply chain coordination and waste reduction for fresh products from the perspective of revenue sharing and preservation technology investment. Qiu et al.[3] further considered strategic consumer behavior and investigated pricing coordination and circulation loss control in fresh agricultural products supply chains.

In recent years, increasing attention has been paid to inter-member collaboration and profit allocation in fresh agricultural products supply chains. Li et al.[4] designed a profit-sharing contract from the perspective of spatio-temporal costs to improve supply chain coordination. Ran and Chen[5] investigated supply chain coordination under a freshness preservation strategy. Li et al.[6] analyzed a profit-sharing mechanism for fresh agricultural products supply chains under the community group purchase mode. These studies suggest that appropriate collaboration mechanisms and profit-sharing arrangements can improve member decisions and enhance overall supply chain profitability.

Although the role of logistics service providers in fresh agricultural products supply chains has been recognized, most existing studies emphasize service outsourcing, supply chain coordination, or contract design between retailers and logistics service providers. Comparatively less attention has been given to the production-logistics collaboration relationship between the supplier and the logistics service provider. In practice, collaboration between the supplier and the logistics service provider not only affects product quality maintenance during circulation, but also changes the wholesale price, purchase quantity, and profit allocation among supply chain members. Therefore, it remains valuable to characterize the decision-making relationship among the supplier, retailer, and logistics service provider under production-logistics collaboration and to analyze the conditions under which collaborative gains can be allocated among the participating members.

Based on this background, this study constructs a fresh agricultural products supply chain model consisting of a supplier, a retailer, and a logistics service provider, and compares the optimal decisions and profit performance under the decentralized operation mode and the production-logistics collaboration mode. Under the decentralized operation mode, the supplier, retailer, and logistics service provider make decisions independently. Under the production-logistics collaboration mode, the supplier and the logistics service provider jointly make decisions with the objective of maximizing the total profit of the production-logistics collaboration, while the retailer still independently determines its purchase quantity. A Stackelberg game is used to derive the optimal wholesale price, purchase quantity, freshness preservation effort level, and member profits under the two modes, and the profit-sharing condition under the production-logistics collaboration mode is further analyzed.

2. Problem Description and Model Assumptions

2.1. Problem Description

This study considers a fresh agricultural products supply chain system composed of a large-scale fresh agricultural products supplier, a retailer, and a logistics service provider, and examines how supply chain members' decisions affect operational performance within a single sales cycle. It is assumed that information is symmetric among the supply chain members, and that the supplier, retailer, and logistics service provider are risk-neutral rational economic agents whose objective is to maximize their own profits. In this supply chain system, the supplier plays a leading role and has certain bargaining power, first determining the wholesale price w of fresh agricultural products. As a follower, the retailer determines the purchase quantity Q after observing the supplier's decision and purchases logistics and freshness preservation services from the logistics service provider. The logistics service provider provides transportation and preservation services according to the retailer's service demand, thereby ensuring that fresh agricultural products enter the consumer market.

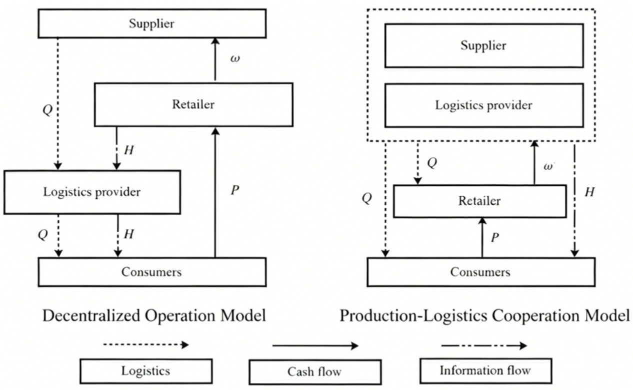

Figure 1. Fresh agricultural products supply chain system with logistics service provider participation

After the sales cycle begins, the retailer signs a procurement contract with the supplier, and the supplier determines the wholesale price w according to market conditions and its own profit objective. The retailer then determines the purchase quantity Q based on the wholesale price, market demand, and the level of logistics and preservation services. After completing product supply, the supplier transfers the fresh agricultural products to the logistics service provider for transportation and preservation. The logistics service provider determines the freshness preservation effort level H according to the retailer's service demand and delivers the products to the sales terminal or consumers. After receiving Q units of fresh agricultural products, the retailer pays the supplier for the goods and pays the logistics service provider for logistics and freshness preservation services. At the end of the sales season, market demand is realized and the retailer obtains sales revenue.

In a fresh agricultural products supply chain, the logistics service provider may participate as an independent operating entity, or it may form a collaborative operating relationship with the upstream supplier. According to whether the supplier and the logistics service provider form a collaborative decision-making arrangement, this study divides the supply chain operation modes into the decentralized operation mode and the production-logistics collaboration mode. The supply chain structure is shown in Figure 1.

2.2. Basic Assumptions and Notation

Before constructing the decision model of the fresh agricultural products supply chain, the following assumptions and notation are introduced.

(1) The supplier's supply cost is $C(Q) = C_1 Q$, where Q denotes the purchase quantity of fresh agricultural products, C_1 denotes the supplier's unit input cost, and $C_1 > 0$.

(2) The retailer's unit operating cost is C_2; therefore, its total operating cost is $C_2 Q$, where $C_2 > 0$. This cost mainly includes transaction processing, marketing promotion, after-sales service, and other operating expenses associated with the purchase quantity.

(3) Since improvement in the logistics service level usually requires additional resources, the logistics service cost is assumed to be related to the freshness preservation effort level H and to increase quadratically, namely

$$C(H) = \frac{1}{2}\varphi H^2.$$

where $\varphi > 0$. Here, H denotes the freshness preservation effort level of the logistics service provider, and φ denotes the freshness preservation effort cost coefficient. A larger φ indicates a higher cost for the logistics service provider to improve its freshness preservation effort level. Let ρ denote the unit service charge coefficient for freshness preservation. Then $H\rho$ denotes the logistics preservation service fee per unit of fresh agricultural product. Similar assumptions can be found in Yu and Xiao[1].

(4)The retail price function of fresh agricultural products is assumed to be $P=a-bQ+kH$. Here, $a(a > 0)$ denotes the maximum acceptable market price, meaning that consumers will not purchase the fresh agricultural product if the retail price exceeds a; $b(b > 0)$ denotes the sensitivity of demand to the retail price; and $k(k>0)$ denotes the sensitivity of the retail price to freshness preservation effort.

The remaining variables and their meanings are shown in Table 1.

Table 1. Notation

Variable	Meaning
w	Wholesale price
Q	Purchase quantity
H	Freshness preservation effort level
π^s	Supplier profit
π^r	Retailer profit
π^l	Logistics service provider profit

Note: Superscript JZ denotes the decentralized operation mode, and superscript CY denotes the production-logistics collaboration mode.

3. Model Construction and Analysis

3.1. Decentralized Operation Mode

Under the decentralized operation mode, each member of the fresh agricultural products supply chain independently makes decisions with the objective of maximizing its own profit. The supplier first determines the wholesale price w, the retailer then determines the purchase quantity Q, and the logistics service provider further chooses the freshness preservation effort level H, thereby forming a three-stage Stackelberg game. The profits of the supplier, retailer, and logistics service provider are denoted by π^s_{JZ}, π^r_{JZ} and π^l_{JZ}, respectively. The supplier's profit is the revenue after deducting the unit supply cost, and its profit function is

$$\pi^s_{JZ}=wQ\text{-}C_1Q.$$

The retailer's profit consists of product sales revenue minus procurement cost, logistics preservation service cost, and operating cost. Its profit function is

$$\pi^r_{JZ}=PQ\text{-}wQ\text{-}H\rho Q\text{-}C_2Q.$$

The logistics service provider's profit is the difference between logistics preservation service revenue and freshness preservation effort cost. Its profit function is

$$\pi^l_{JZ}=H\rho Q\text{-}\frac{1}{2}\varphi H^2.$$

Under the decentralized operation mode, the supply chain members make decisions independently to maximize their respective profits. Based on the above game relationship, the decision model can be formulated as follows:

$$\max_w(\pi^s_{JZ})=wQ\text{-}C_1Q$$
$$s.t.\begin{cases}\max\limits_S(\pi^r_{JZ})=PQ\text{-}wQ\text{-}H\rho Q\text{-}C_2Q\\ \max\limits_S(\pi^l_{JZ})=H\rho Q\text{-}\frac{1}{2}\varphi H^2\end{cases}$$

Solving the model by backward induction gives the following result.

Theorem 1. Under the decentralized operation mode, when $k<\frac{2b\varphi+\rho^2}{\rho}$, all supply chain members can obtain non-negative profits, and the optimal decisions are as follows.

(1)The optimal wholesale price w^*_{JZ}, the retailer's optimal purchase quantity Q^*_{JZ}, and the logistics service provider's optimal freshness preservation effort level H^*_{JZ} are

$$w^*_{JZ}=\frac{a+C_1\text{-}C_2}{2},$$
$$Q^*_{JZ}=\frac{\varphi(a\text{-}C_1\text{-}C_2)}{2(2b\varphi+\rho^2\text{-}k\rho)},$$
$$H^*_{JZ}=\frac{\rho(a\text{-}C_1\text{-}C_2)}{2(2b\varphi+\rho^2\text{-}k\rho)}.$$

(2)The optimal profits of the supplier, retailer, and logistics service provider are

$$\pi^{s*}_{JZ}=\frac{\varphi(a\text{-}C_1\text{-}C_2)^2}{4(2b\varphi+\rho^2\text{-}k\rho)},$$
$$\pi^{r*}_{JZ}=\frac{b\varphi^2(a\text{-}C_1\text{-}C_2)^2}{4(2b\varphi+\rho^2\text{-}k\rho)^2},$$
$$\pi^{l*}_{JZ}=\frac{\rho^2\varphi(a\text{-}C_1\text{-}C_2)^2}{8(2b\varphi+\rho^2\text{-}k\rho)^2}.$$

Property 1. Under the decentralized operation mode, the optimal purchase quantity Q^*_{JZ} and the optimal freshness preservation effort level H^*_{JZ} decrease with demand price sensitivity b and increase with the preservation-effort price-impact coefficient k, namely

$$\frac{\partial Q^*_{JZ}}{\partial b}<0,\frac{\partial H^*_{JZ}}{\partial b}<0;\ \frac{\partial Q^*_{JZ}}{\partial k}>0,\frac{\partial H^*_{JZ}}{\partial k}>0.$$

Property 1 indicates that under the decentralized operation mode, a higher demand price sensitivity strengthens the inhibitory effect of retail price increases on market demand. As a result, the retailer reduces its optimal purchase scale, which further weakens the profit space generated by the logistics service provider's preservation input and lowers the optimal freshness preservation effort level. By contrast, a higher preservation-effort price-impact coefficient means that preservation effort can more effectively increase the market value of the product. Therefore, the logistics service provider has a stronger incentive to improve its preservation effort level, and the retailer correspondingly expands its purchase scale.

3.2. Production-Logistics Collaboration Mode

Under the production-logistics collaboration mode, the supplier and the logistics service provider form a joint decision-making entity. Instead of separately pursuing local profit maximization, they jointly consider product supply revenue and logistics preservation service revenue, and determine the wholesale price and freshness preservation effort level with the objective of maximizing their joint profit. The retailer remains an independent decision-making entity and determines the purchase quantity according to the wholesale price and the preservation service level. Therefore, under this mode, the supply chain evolves into a two-stage Stackelberg game between the supplier-logistics service provider joint entity and the retailer. The profits of the retailer and the supplier-logistics service provider joint entity are denoted as follows. The retailer's profit consists of product sales revenue minus procurement cost, logistics preservation service fee, and operating cost:

$$\pi^r_{CY}=PQ\text{-}wQ\text{-}H\rho Q\text{-}C_2Q.$$

The profit of the supplier-logistics service provider joint entity consists of the supplier's transaction revenue and the logistics service provider's preservation service revenue, minus the product supply cost and the freshness preservation effort cost:

$$\pi^{sl}_{CY}=wQ\text{-}C_1Q+H\rho Q\text{-}\frac{1}{2}\varphi H^2.$$

Under the production-logistics collaboration mode, the supply chain members still aim to maximize profits, but the supplier and the logistics service provider no longer make separate local decisions. Instead, they jointly make decisions to maximize their combined profit. Based on the above game relationship, the decision model can be written as

$$\max_w(\pi^r_{CY})=PQ\text{-}wQ\text{-}H\rho Q\text{-}C_2Q$$
$$s.t.\ \max_{Q,H}(\pi^{sl}_{CY})=wQ\text{-}C_1Q+H\rho Q\text{-}\frac{1}{2}\varphi H^2$$

Solving the model by backward induction gives the following result.

Theorem 2. Under the production-logistics collaboration mode, when $k<2\sqrt{b\varphi}$, all supply chain members can obtain non-negative profits, and the optimal decisions are as follows.

(1)The optimal wholesale price w^*_{CY}, optimal purchase quantity Q^*_{CY}, and optimal freshness preservation effort level H^*_{CY} are

$$w^*_{CY}=C_1+\frac{(2b\varphi\text{-}k\rho)(a\text{-}C_1\text{-}C_2)}{4b\varphi\text{-}k^2},$$
$$Q^*_{CY}=\frac{\varphi(a\text{-}C_1\text{-}C_2)}{4b\varphi\text{-}k^2},$$
$$H^*_{CY}=\frac{k(a\text{-}C_1\text{-}C_2)}{4b\varphi\text{-}k^2}.$$

(2)The optimal profits of the retailer and the supplier-logistics service provider joint entity are

$$\pi_{CY}^{r} = \frac{b\varphi^2(a\text{-}C_1\text{-}C_2)^2}{(4b\varphi\text{-}k^2)^2},$$

$$\pi_{CY}^{sl} = \frac{\varphi(a\text{-}C_1\text{-}C_2)^2}{2(4b\varphi\text{-}k^2)}.$$

Property 2. Under the production-logistics collaboration mode, the optimal purchase quantity Q_{CY}^{*} and the optimal freshness preservation effort level H_{CY}^{*} decrease with demand price sensitivity b and increase with the preservation-effort price-impact coefficient k, namely

$$\frac{\partial Q_{CY}^{*}}{\partial b} < 0, \frac{\partial H_{CY}^{*}}{\partial b} < 0; \frac{\partial Q_{CY}^{*}}{\partial k} > 0, \frac{\partial H_{CY}^{*}}{\partial k} > 0.$$

Property 2 shows that under the production-logistics collaboration mode, an increase in demand price sensitivity reduces the room for market demand expansion. The collaborative entity therefore reduces the optimal purchase quantity and lowers the revenue conversion effect of preservation investment, which causes the optimal freshness preservation effort level to decline. Conversely, a higher preservation-effort price-impact coefficient strengthens the value conversion capability of preservation effort, making the collaborative entity more willing to increase the preservation effort level and expand the optimal purchase quantity through enhanced product market value.

Property 3. Under the production-logistics collaboration mode, the preservation service charge coefficient ρ does not affect the optimal purchase quantity or the optimal freshness preservation effort level, but reduces the optimal wholesale price, namely

$$\frac{\partial w_{CY}^{*}}{\partial \rho} < 0$$

Under the production-logistics collaboration mode, the supplier and the logistics service provider have formed a unified decision-making entity. The logistics preservation service charge is no longer merely an external transaction price, but serves more as a profit allocation adjustment variable among the supplier, logistics service provider, and retailer. Therefore, a change in ρ does not alter the optimal purchase quantity or preservation effort decision under this collaboration mode, but it is reflected through the adjustment of the wholesale price.

4. Comparison of Operation Modes

The preceding sections derive the game-theoretic optimal solutions under the decentralized operation mode and the production-logistics collaboration mode. This section further compares the decision behavior of supply chain members under the two modes.

Property 4. When the existence conditions for the optimal solutions are satisfied, compared with the decentralized operation mode, the production-logistics collaboration mode simultaneously increases the optimal purchase quantity, the retailer's optimal profit, and the total profit of the supplier and the logistics service provider, namely

$$Q_{JZ}^{*} < Q_{CY}^{*}, \pi_{JZ}^{r*} < \pi_{CY}^{r*}, \pi_{JZ}^{s*} + \pi_{JZ}^{l*} < \pi_{CY}^{sl*}.$$

This property suggests that the production-logistics collaboration mode integrates the decision objectives of the supplier and the logistics service provider, thereby mitigating the local decision conflict between product supply and logistics services under the decentralized operation mode and improving the overall operational performance of the supply chain. Specifically, this collaboration mode not only expands the retailer's optimal purchase scale and promotes the circulation scale of fresh agricultural products, but also improves the retailer's profit, indicating that collaborative operation can improve trading conditions and enhance retail-end returns. In addition, production-logistics collaboration incorporates product supply revenue and preservation service revenue into a unified objective function, avoiding the decision separation caused by the supplier and the logistics service provider independently maximizing their own profits under the decentralized operation mode. As a result, it improves their joint profit. Therefore, the production-logistics collaboration mode outperforms the decentralized operation mode in terms of purchase scale, retailer profitability, and the joint profitability of the supplier and the logistics service provider.

Property 5. Suppose the supplier and the logistics service provider allocate the joint profit under the production-logistics collaboration mode according to the profit-sharing coefficient λ. Both the supplier and the logistics service provider can obtain higher profits under the production-logistics collaboration mode than under the decentralized operation mode if λ satisfies

$$\frac{4b\varphi\text{-}k^2}{2(b\varphi+\rho^2\text{-}k\rho)} < \lambda < 1 - \frac{\rho^2(4b\varphi\text{-}k^2)}{4(b\varphi+\rho^2\text{-}k\rho)^2}.$$

The profits of the supply chain members under the two modes are shown in Table 2.

Table 2. Profit allocation of supply chain members under different modes

Mode	Supplier	Retailer	Logistics service provider
Decentralized operation mode	π_{JZ}^{s*}	π_{JZ}^{r*}	π_{JZ}^{l*}
Production-logistics collaboration mode	$\lambda\pi_{CY}^{sl*}$	π_{CY}^{r*}	$(1\text{-}\lambda)\pi_{CY}^{sl*}$

This property indicates that although the production-logistics collaboration mode can increase the joint profit of the supplier and the logistics service provider, whether both parties can benefit simultaneously depends on the joint profit allocation mechanism. A reasonable profit-sharing interval can ensure that both the supplier and the logistics service provider have incentives to participate in collaborative operation.

5. Numerical Analysis

Based on the preceding analysis, this section conducts numerical analysis to examine changes in supply chain members' decisions and profits under different modes. For convenience, the parameters are set as shown in Table 3.

Table 3. Parameter settings

a	C_1	C_2	ρ	φ
10	1	2	0.6	1

As k increases, the optimal freshness preservation effort levels under both the decentralized operation mode and the production-logistics collaboration mode show an upward trend. This indicates that when freshness preservation effort has a stronger positive effect on the retail price, supply chain members tend to increase preservation investment. By comparison, H^* under the production-logistics collaboration mode is more sensitive to changes in k. When k is relatively high, the preservation effort level under this mode is significantly higher than that under the decentralized operation mode. However, when k is relatively low, the preservation effort level under the production-logistics collaboration mode may be lower than that under the decentralized operation mode, indicating that the relative magnitude of preservation effort under the two modes is not constant.

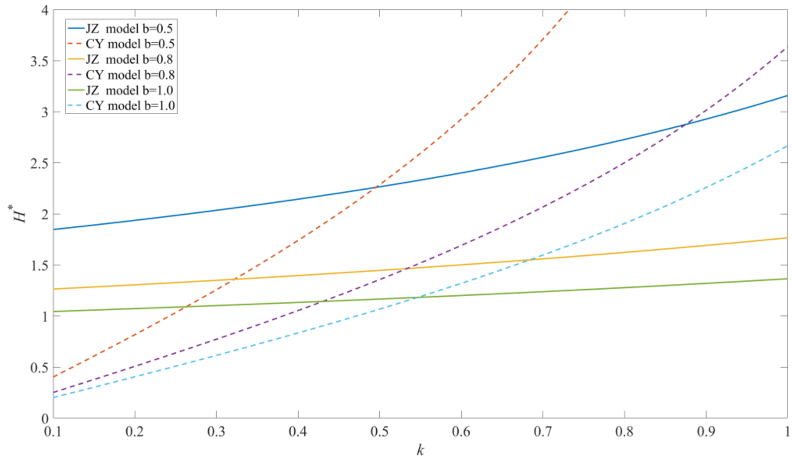

Figure 2. Effect of k on optimal freshness preservation effort level for different values of b

In addition, as b increases, the optimal preservation effort level generally declines, suggesting that higher demand price sensitivity limits the revenue conversion space of preservation investment.

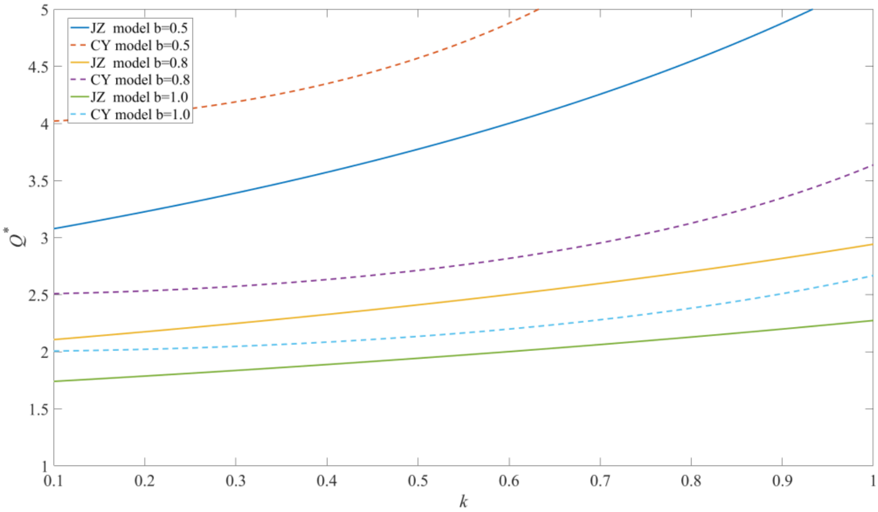

Figure 3. Effect of k on optimal purchase quantity for different values of b

As shown in Figure 3, as k increases, the optimal purchase quantities under both modes increase. This suggests that the stronger the ability of freshness preservation effort to enhance retail value, the more willing the retailer is to expand its purchase scale. Under the same b and k conditions, the optimal purchase quantity under the production-logistics collaboration mode is always higher than that under the decentralized operation mode. This indicates that the production-logistics collaboration mode expands the purchase quantity by integrating the decision objectives of the supplier and the logistics service provider. Across different levels of b, a smaller b corresponds to a larger purchase quantity, whereas a larger b corresponds to a smaller purchase quantity. This means that when consumers are less sensitive to price, the retailer can undertake a larger purchase scale; when demand price sensitivity is higher, the retailer reduces the purchase quantity to lower the risk associated with market demand decline.

Overall, as k increases, the retailer's profit under both modes increases, indicating that a stronger positive impact of freshness preservation effort on the retail price enables the retailer to obtain higher returns through product value enhancement. Under the same b and k conditions, the retailer's profit under the production-logistics collaboration mode is always higher than that under the decentralized operation mode. This shows that although the retailer is not included in the joint entity, production-logistics collaboration can still improve the retailer's profit by expanding the purchase quantity, enhancing the value of preservation investment, and improving transaction conditions. In addition, the retailer's profit is higher when b is smaller, and the growth rate of profit with respect to k is more pronounced. This implies that the production-logistics collaboration mode is more beneficial for products with lower demand price sensitivity and stronger freshness value conversion capability

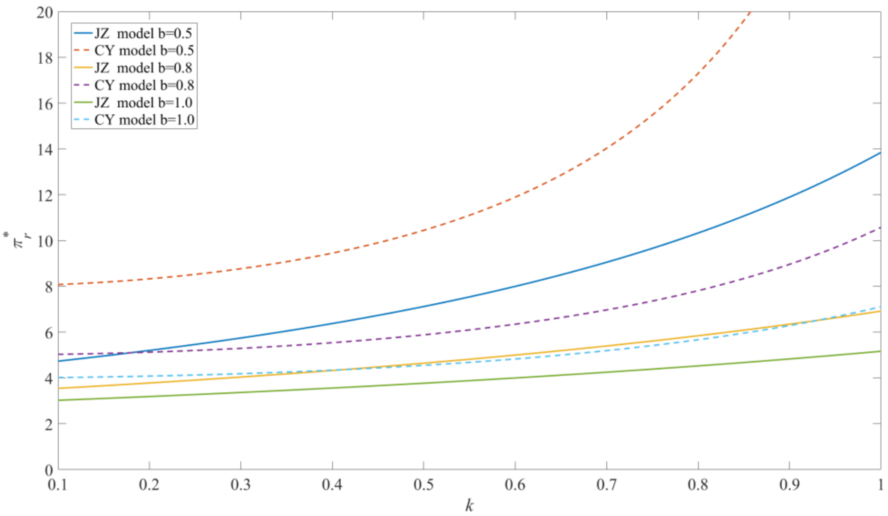

Figure 4. Effect of *k* on retailer's optimal profit for different values of *b*

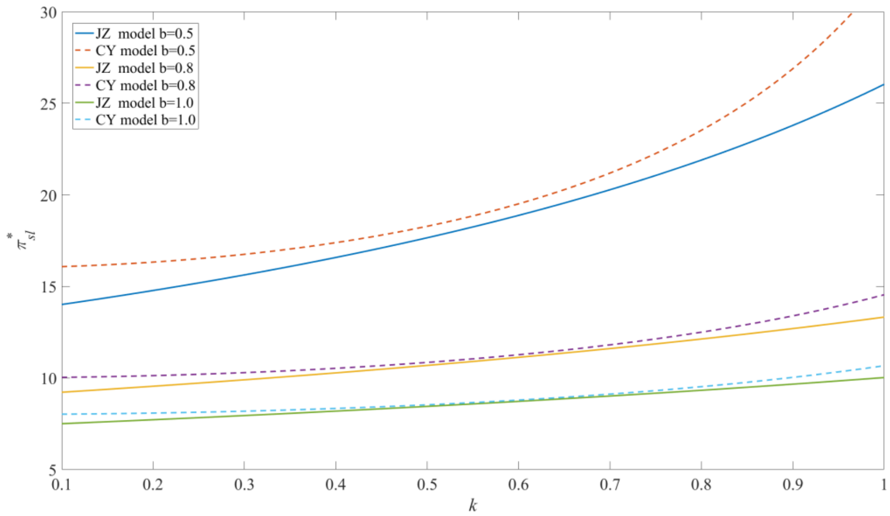

Figure 5. Effect of *k* on supplier-logistics service provider profit for different values of *b*

Overall, as k increases, the profit related to the supplier and the logistics service provider under both modes increases, suggesting that stronger price conversion capability of preservation effort leads to higher returns in product supply and logistics service activities. Under the same b and k conditions, the profit under the production-logistics collaboration mode is always higher than that under the decentralized operation mode. This indicates that after the supplier and the logistics service provider form a joint entity, unified decision-making can enhance their overall profit. Meanwhile, a smaller b corresponds to a higher profit level, whereas a larger b corresponds to a lower profit level. This means that higher demand price sensitivity strengthens the suppressive effect of price changes on market demand and compresses the profit space. Therefore, the production-logistics collaboration mode is more suitable for fresh agricultural products with low demand price sensitivity and strong freshness value conversion capability.

6. Conclusion

Fresh agricultural products supply chains require effective coordination between product supply and logistics services because freshness preservation directly influences product value and market demand. Based on a three-tier supply chain system composed of a supplier, a retailer, and a logistics service provider, this paper compares decentralized operation with production-logistics collaboration and derives the corresponding optimal decisions and profit outcomes.

The results indicate that demand price sensitivity negatively affects both the optimal purchase quantity and the freshness preservation effort level. As consumers become more price-sensitive, supply chain members tend to reduce procurement scale and preservation investment. In contrast, a higher coefficient measuring the impact of freshness preservation effort on the retail price strengthens the value conversion effect of preservation activities, thereby promoting higher purchase quantity, greater preservation effort, and improved member profits.

Compared with decentralized operation, production-logistics collaboration increases the optimal purchase quantity, the retailer's profit, and the joint profit of the supplier and the logistics service provider. This demonstrates that collaborative operation can alleviate the inefficiency caused by separated production and logistics decisions and improve supply chain performance. Nevertheless, the sustainability of collaboration depends on a reasonable profit-sharing mechanism. Only when both the supplier and the logistics service provider obtain no less profit than under decentralized operation will they have incentives to participate in collaboration.

In general, production-logistics collaboration is more applicable to fresh agricultural products with low demand price sensitivity and strong freshness value conversion capability. Future research may extend the model by considering demand uncertainty, product deterioration, and competition among multiple retailers.

7. Managerial Implications

The findings suggest that fresh agricultural products supply chains should place greater emphasis on production-logistics collaboration. Since product freshness is closely related to logistics preservation effort, independent decision-making by the supplier and the logistics service provider may lead to inefficient coordination between product supply and logistics services. By establishing a collaborative decision-making mechanism, the supplier and the logistics service provider can jointly optimize wholesale pricing and freshness preservation effort, thereby improving the retailer's purchase quantity and enhancing the overall profitability of the supply chain.

Consumer price sensitivity should also be considered when managers formulate operational strategies. When consumers are highly sensitive to price, excessive preservation investment or aggressive pricing may weaken market demand and reduce profit margins. Therefore, for products with high demand price sensitivity, firms should focus on cost control, demand forecasting, and flexible pricing. For products whose freshness can be effectively converted into market value, firms may appropriately increase investment in cold-chain logistics, preservation technology, and delivery efficiency.

A reasonable profit-sharing mechanism is essential for maintaining the stability of production-logistics collaboration. Although collaboration can increase the joint profit of the supplier and the logistics service provider, the sustainability of such collaboration depends on whether both parties can obtain acceptable returns. Therefore, enterprises should design appropriate profit-sharing, cost-sharing, or compensation mechanisms to ensure that the benefits generated by collaboration are fairly allocated. This can enhance the willingness of both parties to participate in long-term cooperative operations.

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