Research on the Impact of Different Power Structures on the Supply Chain of Fresh Produce

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Abstract: Considering the influence of fresh-keeping effort level and value-added service level on consumer demand in the sales process of fresh e-commerce platform, the consumer demand function under the joint influence of fresh-keeping effort level and value-added service level was constructed, and a single fresh food manufacturer and a single fresh e-commerce platform were studied (hereinafter replaced by retailers) constitutes the influencing factors of the secondary fresh e-commerce supply chain. By constructing the manufacturer-led and retailer-led fresh e-commerce supply chain decision model, the influence of freshness demand elasticity coefficient, value-added service elasticity factor and other factors on optimal decision-making is analyzed. The optimal decision of the two modes is compared. The results show that: 1) under the dominance of retailers and the elasticity coefficient of value-added services is low, the direct sales price and demand of the channel are the highest, but the preservation efforts provided by the manufacturer are higher, and the profit of the retailer will be much higher than the profit of the manufacturer; (2) When the manufacturer is led and the elasticity coefficient of value-added services is low, the overall profit of the supply chain is the lowest at this time.

Keywords: Different Power Structures, Freshness Preservation Efforts, Value-Added Services.

1 INTRODUCTION

With the rapid development of the Internet and the rapid popularity of e-commerce. As of 2020, China's fresh e-commerce market has developed rapidly, with the scale of the fresh e-commerce industry reaching 458.5 billion yuan, an increase of 64.0% over 2019. It is expected that fresh e-commerce will maintain rapid growth for a period of time in the future, and the scale of the fresh e-commerce industry will exceed one trillion yuan by 2023. In this context, it is of great significance to explore the cooperative relationship and optimal decision-making of value-added services and preservation efforts on the main parties of the supply chain, which is of great significance to improve the performance of the supply chain of fresh agricultural products.

The literature related to the research in this paper mainly focuses on two directions. The first research direction is the study of supply chain decision-making under different power structures. The questions they study vary from issue to issue. Wang et al. (2017) and Sun et al. (2020) consider the situation where different supply chain members have dual-channel supply chains. Choi (1991) and Shi et al. (2013) explore the impact of different power structures on supply chain members under different demand function forms. Zhang Guoxing et al. (2015), when

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considering wholesale price as an exogenous variable, concluded that a single member of the supply chain can always benefit from market dominance, but for the entire supply chain channel, whether dominance is beneficial depends on the market potential comparison between the two channels. Liu et al. (2022) construct a two-tier transnational green supply chain model led by manufacturers and retailers, respectively, when considering tariffs, supply chain power structure, and consumers' green preferences. Li Xinran et al. (2018) constructed a closed-loop supply chain system composed of individual manufacturers and retailers under the consideration of free riders, and explored the influence mechanism of different power structures on the decision-making of closed-loop supply chain system.

The second research direction is the study of the dual effort factors of the supply chain. Bai Shizhen et al. (2018), Liu Molin et al. (2020) considered the impact of fresh-keeping efforts and promotion efforts, and fresh-keeping efforts and value-added services on fresh e-commerce supply chain decisions. Zhang Chong, Liu Ying et al. (2021) consider the quality efforts of manufacturers and the sales efforts of retailers in the model. Hua (2001) takes into account the advertising promotion method in the model.

The main differences between this paper and the aforementioned literature are: (1) the impact of fresh-keeping effort coefficient and value-added service coefficient on supply chain decision-making under different power structures is studied, while existing studies have not considered the dual impact of fresh-keeping effort and value-added service together; Or do not consider different supply chain power structures; (2) With the popularity of the Internet and the rapid development of self-media, product pricing information has become more and more transparent, so this article takes wholesale price as an exogenous variable.

2 DESCRIPTION OF THE PROBLEM AND PARAMETERIZATION

This paper considers a supply chain consisting of a fresh manufacturer (M) and a retailer (O), in which the fresh manufacturer is responsible for activities such as the production, packaging and other activities of the fresh product, that is, the cost per unit of fresh product produced is c; The retailer is responsible for selling fresh products at a price and providing consumers with relevant value-added services e2, including promotions and content services related to fresh products [11], and after the consumer places a successful order, the retailer is responsible for delivery, and the supplier provides freshness preservation measures.

This paper expresses the demand function of fresh products as:

$$d = 1 - p + \alpha\theta_0 e_1 + \beta e_2 \qquad (1)$$

where d represents the demand of the channel, α ($\alpha > 0$) represents the freshness elasticity coefficient, θ_0 represents the initial freshness of fresh product distribution, e_1 ($e_1 > 0$) represents the level of freshness preservation effort, β ($\beta > 0$) represents the elastic coefficient of value-added services, and e_2($e_2 > 0$) represents the value-added service level $\alpha > \beta$.

Suppose the manufacturer's cost of freshness and the retailer's cost of providing value-added services are respectively:

$$C(e_1) = \frac{1}{2}k_1 e_1^2 \tag{2}$$

$$C(e_2) = \frac{1}{2}k_2 e_2^2 \tag{3}$$

where $C(e_1)$ represents the manufacturer's freshness cost, $k_1>0$ represents the manufacturer's product freshness cost coefficient; $C(e_2)$ represents the cost of value-added services paid by retailers, and $k_2(k_2>0)$ represents the retailer's value-added service cost factor.

In summary, the profits of manufacturers and retailers in the secondary supply chain are respectively

$$\pi_m(e_1) = (w-c)d - \frac{1}{2}k_1 e_1^2 \tag{4}$$

$$\pi_o(p, e_2) = (p-w)d - \frac{1}{2}k_2 e_2^2 \tag{5}$$

where Π_m represents the manufacturer's profit, Π_o represents the retailer's profit, and w is an exogenous variable that represents the wholesale price determined by a long-term contract.

For clarity, the symbols used in this model are specified as follows: the superscript * in the symbol represents the optimal solution (or optimal target value) of the corresponding optimization model. The meaning of symbols other than these will be explained in the text.

3 SUPPLY CHAIN DECISIONS UNDER DIFFERENT POWER STRUCTURES

3.1 Manufacturer-led supply chain decisions (M)

In the M model, the decision order is: the manufacturer first determines the freshness of the fresh produce e1, then the retailer decides the retail price of the product p and the value-added service e2, and the profit of the manufacturer and retailer is (4) (5) respectively.

Theorem 1 Manufacturer-led, when $2k_2 - \beta^2 > 0$, by reverse induction, the optimal equilibrium decision between supplier and retailer is:

Optimal freshness preservation efforts:

$$e_1^{M^*} = \frac{(w-c)k_2\alpha\theta_0}{k_1(2k_2-\beta^2)};$$

Optimal value-added services for retailers:

$$e_2^M = \frac{\beta + \alpha\beta\theta_0 e_1 - \beta w}{2k_2 - \beta^2};$$

Optimal retail price for retailers:

$$p^{M^*} = \frac{k_1 k_2 \left(2k_2 - \beta^2\right) - c k_2^2 \alpha^2 \theta_0^2 + w\left[k_2^2 \alpha^2 \theta_0^2 + \left(k_2 - \beta^2\right)\left(2k_2 - \beta^2\right) k_1\right]}{k_1 \left(2k_2 - \beta^2\right)^2};$$

The total demand is:

$$d^{M^*} = \frac{k_1 k_2 \left(2k_2 - \beta^2\right) - c k_2^2 \alpha^2 \theta_0^2 + w\left[k_2^2 \alpha^2 \theta_0^2 - k_1 k_2 \left(2k_2 - \beta^2\right)\right]}{k_1 \left(2k_2 - \beta^2\right)^2};$$

The total profits of manufacturers and retailers are:

$$\pi_m^{M^*} = \frac{k_1 k_2 \left(2k_2 - \beta^2\right)(w-c) + c^2 k_2^2 \alpha^2 \theta_0^2 - 2wc\left(k_2^2 \alpha^2 \theta_0^2 - k_1 k_2 \left(2k_2 - \beta^2\right)\right) + w^2 \left(k_2^2 \alpha^2 \theta_0^2 - 2k_1 k_2 \left(2k_2 - \beta^2\right)\right)}{2k_1 \left(2k_2 - \beta^2\right)^2}$$

$$\pi_o^{M^*} = \frac{k_2 \left[k_1 \left(2k_2 - \beta^2\right) - c k_2 \alpha^2 \theta_0^2 + w\left(k_2 \alpha^2 \theta_0^2 - k_1 \left(2k_2 - \beta^2\right)\right)\right]^2}{2k_1^2 \left(2k_2 - \beta^2\right)^3}.$$

3.2 Retailer-led supply chain decisions (O)

In the O model, the decision order is: the retailer first determines the retail price of the product p and the value-added service e_2, the supplier determines the freshness of the fresh produce e_1, and the profit of the manufacturer and retailer are equation (4) (5) respectively.

Theorem 2 Under manufacturer dominance, when $2k_2 - \beta^2 > 0$, the optimal equilibrium decision between manufacturer and retailer is:

Optimal freshness preservation efforts of manufacturers: $e_1^{o^*} = \frac{(w-c)\alpha\theta_0}{k_1}$;

Optimal value-added services for retailers:

$$e_2^{o^*} = \frac{\beta\left[k_1 + w(\alpha^2 \theta_0^2 - k_1) - c\alpha^2 \theta_0^2\right]}{k_1 \left(2k_2 - \beta^2\right)};$$

Optimal retail price for retailers:

$$p^{o^*} = \frac{k_2 (k_1 - c\alpha^2 \theta_0^2) + w\left(k_2 \alpha^2 \theta_0^2 + k_1 \left(k_2 - \beta^2\right)\right)}{k_1 \left(2k_2 - \beta^2\right)};$$

The total demand: $d^{O^*} = \dfrac{k_2\left[k_1 - c\alpha^2\theta_0^2 + w\left(\alpha^2\theta_0^2 - k_1\right)\right]}{k_1\left(2k_2 - \beta^2\right)}$;

The total profits of manufacturers and retailers:

$$\pi_m^{O^*} = \frac{2k_1k_2(w-c) + 2wc\left(k_1k_2 - \beta^2\alpha^2\theta_0^2\right) - w^2(2k_1k_2 - \beta^2\alpha^2\theta_0^2) + c^2\alpha^2\theta_0^2\beta^2}{2k_1\left(2k_2 - \beta^2\right)}$$

$$\pi_0^{O^*} = \frac{k_2\left[k_1 - c\alpha^2\theta_0^2 + w\left(\alpha^2\theta_0^2 - k_1\right)\right]^2}{2k_1\left(2k_2 - \beta^2\right)}.$$

4 COMPARATIVE ANALYSIS AND CASE ANALYSIS

In this section, the impact of different power structures in the supply chain on direct prices, freshness preservation efforts and value-added services, demand, and revenue of supply chain members is discussed.

Firstly, by comparing and analyzing the impact of the power structure of different supply chains on the direct selling price decisions of supply chain members, the following conclusions can be drawn.

Proposition 1 In the M game and the O game, the direct selling price under the M game is greater than the direct selling price under the O game. Namely $p^{M^*} < p^{O^*}$.

According to proposition 1, it can be seen that the direct sales price in the O model is greater than the direct sales in the M model; The reasons and mechanisms can be explained as: retailers have greater initiative when they are the dominant players, so retailers will set direct sales prices that are conducive to the growth of their own interests; In the M model, manufacturers do not want retailers to set excessively high retail prices in order to increase consumer demand and ensure their own profits.

Secondly, by comparing and analyzing the impact of power structures in different supply chains on manufacturers' freshness preservation efforts and retailers' value-added service decisions, the following conclusions can be drawn.

Proposition 2

(1) when $0 < \beta < \sqrt{k_2}$, $e_1^{M^*} < e_1^{O^*}$;when $\sqrt{k_2} < \beta < \sqrt{2k_2}$, $e_1^{M^*} > e_1^{O^*}$;

(2) $\dfrac{\partial e_2^{M^*}}{\partial \alpha} > 0$, $\dfrac{\partial e_2^{M^*}}{\partial \beta} > 0$; $\dfrac{\partial e_2^{O^*}}{\partial \alpha} > 0$, $\dfrac{\partial e_2^{O^*}}{\partial \beta} > 0$.

According to the (1) of proposition 2, the following explanation can be made: under the O model, retailers will reduce the cost of value-added services, and then hope that suppliers will improve the freshness of fresh products, thereby stimulating consumers' demand for fresh products, and retailers will get more profits from them, but under the M model, improving the freshness of fresh products requires suppliers to invest in preservation costs, and their profits will decline, so suppliers will not invest too much preservation efforts to ensure their own profits. From (2), it can be seen that whether it is M or O model, the supplier's freshness preservation effort is positively correlated with the freshness preservation effort coefficient and the value-added service coefficient. This phenomenon can be explained as: in the M or O model, whether the supplier improves the freshness preservation effort or the retailer improves the value-added service, the supplier's freshness preservation effort can be improved. Thirdly, by comparing and analyzing the impact of different supply chain power structures on demand decision-making, the following conclusions can be drawn.

Proposition 3 when $0<\beta<\sqrt{k_2-\frac{c}{w-c}}$, $d^{M^*}<d^{O^*}$;when $\sqrt{k_2-\frac{c}{w-c}}<\beta<1$, $d^{M^*}>d^{O^*}$.

According to proposition 3, when consumers are not particularly sensitive to the value-added services provided by retailers, the total demand for the supply chain under the O model is greater than that under the M model; When consumers are sensitive to the value-added services provided by retailers, the total demand for the supply chain under the M model is greater than under the O model, which is obviously consistent with the facts.This is because when consumers' sensitivity to value-added services is $\left(0,\sqrt{k_2-\frac{c}{w-c}}\right)$ within the range, retailers will provide higher value-added services to attract more consumers to buy fresh products, and the increase in demand brought by value-added services is greater than the decrease in demand caused by the increase in direct sales prices led by retailers, and the total demand of the final supply chain shows a growing trend.When consumers' sensitivity to value-added services is $\left(\sqrt{k_2-\frac{c}{w-c}},1\right)$ within the range, although consumers attach more importance to the value-added services provided by retailers, as can be seen from proposition 1, the direct sales price under the M model is the lowest, so the demand led by suppliers is the largest.

Finally, by comparing and analyzing the impact of power structures in different supply chains on manufacturers' profits and retailers' profits, the following conclusions can be drawn.

Proposition 4 (1) ${\pi_{\mathrm{m}}}^{M^*}>{\pi_{\mathrm{m}}}^{O^*}$;(2) $\frac{\partial {\pi_{\mathrm{o}}}^{M^*}}{\partial\alpha}>0$, $\frac{\partial {\pi_{\mathrm{o}}}^{O^*}}{\partial\beta}<0$.

According to (1) of proposition 4, it can be seen that in the M model, the manufacturer is the leader and has absolute power in the supply chain, so the supplier will make a series of decisions to maximize its profits. It can be seen from (2) that in the retailer-led model, the profit of retailers increases with the increase of the manufacturer's freshness preservation coefficient, and decreases with the increase of the retailer's value-added service coefficient. This phenomenon can be explained by the fact that in the case of supplier-led, although the cost of freshness preservation efforts continues to increase, suppliers will still increase the freshness of fresh agricultural products in order to obtain more profits, thereby expanding the demand for channels, and retailers' profits will increase; The greater the cost of value-added services borne by retailers, the lower their profits.

Due to the limitation of space, in this chapter, this paper only discusses the impact of freshness demand elasticity and service demand elasticity parameters on the profits of fresh suppliers, and this paper sets the relevant parameters based on the model assumptions, setting the parameters: $c=0.1$, $w=0.5$, $\alpha=5$, $\beta=4$, $\theta_0=0.9$, $k_1=20$, $k_2=25$.

It can be seen from Figure 1 that the increase in α has a positive effect on the profit of suppliers under the M/O mode, but under the M model, the impact of α on the profit of suppliers is more significant. As can be seen from Figure 2, when the β is small, the profit of the supplier in the M mode is larger; When the β is large, the opposite is true, and these situations are similar to our conclusions above.

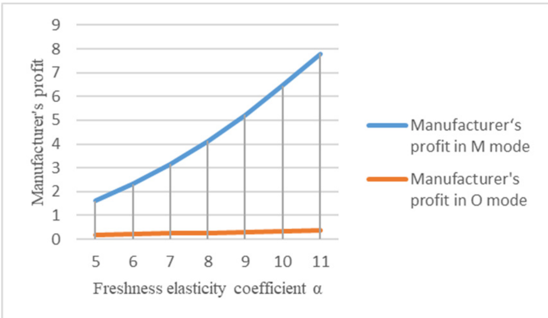

Figure 1 The impact of freshness elasticity coefficient on supplier profits

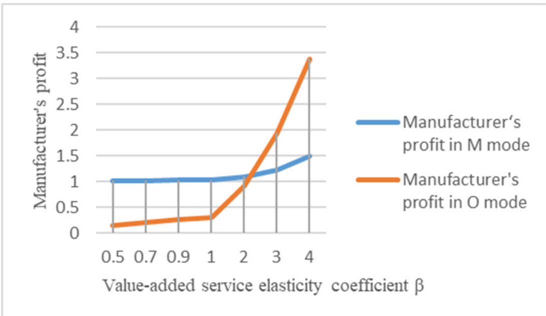

Figure 2 The impact of the elasticity coefficient of value-added services on the profit of suppliers

5 EPILOGUE

In this paper, the optimal decision-making under the two supply chain structures is compared and analyzed in a two-tier supply chain consisting of a fresh food manufacturer and a retailer. It is found that: (1) under the dominance of retailers and the elasticity coefficient of value-added services is low, the direct sales price and demand of the channel are the highest, but the preservation efforts provided by the manufacturer are higher, and the profit of the retailer will be much higher than the profit of the manufacturer; (2) When the manufacturer is led and the elasticity coefficient of value-added services is low, the overall profit of the supply chain is the lowest at this time, so in this case, the manufacturer should delegate authority to the retailer.

It should be pointed out that there are many research directions that can be extended in this paper. For example, a simple secondary supply chain can be extended to multiple manufacturers, multiple retailers, and a cost-sharing contract can be added to determine a threshold that optimizes the profits of both manufacturers and retailers.

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