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Research on Optimization Strategies of Supply Chain Pricing and Returns Management under O2O Model

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Abstract: With the rapid development of information technology and the continuous innovation of e-commerce model, the level of supply chain management has become a key element of the core competitiveness of enterprises. Under the O2O e-commerce model, the lack of coordinated pricing mechanism in the supply chain and the imperfection of returns management have seriously restricted the improvement of the overall efficiency of the supply chain. Based on Stackelberg game theory, this paper constructs a two-level supply chain model consisting of a single supplier and an e-commerce retailer, and through comparative analysis, it is found that the cooperative pricing strategy can significantly enhance the overall benefit of the supply chain, and the coordinated pricing mechanism based on the revenue-sharing contract can effectively promote the long-term and stable cooperation among supply chain members. Regarding the returns management problem, the study systematically classifies the types of product returns, then designs a standardized returns strategy scheme, and confirms the relative advantage of the exchange mode by comparing the impact of four typical returns modes on the supply chain profit. On this basis, this study proposes specific measures to optimize the supply chain returns management. The research results provide theoretical basis and practical guidance for O2O e-commerce enterprises to improve their supply chain management level.

Keywords: O2O Model; Supply Chain Management; Stackelberg Game; Revenue-Sharing Contract.

1. Introduction

In recent years, with the rapid development of e-commerce, O2O (Online to Offline) model, as an important bridge connecting online transactions and offline services, has become an important development direction of modern retail industry[1]. Under the O2O e-commerce model, the efficient synergy of the supply chain is crucial to the market competitiveness of enterprises[2], while pricing management and returns management, as key links in the supply chain operation, directly affect the overall profitability and stability of the supply chain. However, the current O2O supply chain still faces many challenges: on the one hand, pricing decisions between the supplier and the e-commerce retailer often lack effective coordination[3], leading to uneven distribution of supply chain profits, and even triggering channel conflicts; on the other hand, consumers return goods more and more frequently, and the lack of a scientific management mechanism will increase the operating costs of the e-commerce retailer and reduce the overall efficiency of the supply chain[4].

In this context, how to optimize the pricing strategy of O2O supply chain to promote the long-term cooperation between the supplier and the e-commerce retailer, as well as how to design a reasonable returns management mechanism to reduce unnecessary losses, have become the key issues of concern for both academics and enterprises. Based on Stackelberg game theory, this study constructs a two-level supply chain model consisting of a single supplier and an e-commerce retailer, explores the impacts of cooperative pricing and non-cooperative pricing on supply chain benefits[5], and designs a coordinated pricing strategy using a revenue-sharing contract to enhance the overall profits of the supply chain. Meanwhile, for the returns management problem, the study divides the returns types by system, compares and analyzes the impacts of different returns modes (e.g., returns and refunds, no returns and refunds, exchanges, refuse returns and refuse refunds, etc.) on the optimal profits of the supply chain, and puts forward optimization suggestions, with a view to providing theoretical support and practical guidance for O2O e-commerce enterprises to improve the level of supply chain management.

2. Problems of Supply Chain Management under O2O Model

With the vigorous development of O2O e-commerce, the pricing strategy of suppliers in supply chain management is increasingly characterized by complexity. In this context, the pricing behavior of suppliers often deviates from the optimal equilibrium, which is mainly manifested in the phenomenon of inflated prices. In-depth analysis of its internal mechanism, there are mainly the following two reasons.

Firstly, from the game theory perspective, suppliers have a clear first-mover advantage in the supply chain, and can observe the decision-making behavior of e-commerce retailers in advance. This sequential decision-making process puts e-commerce retailers in a follower position, and their retail pricing must refer to the wholesale prices set by suppliers, leading to structural differences in profit margins between the two sides. Secondly, from the viewpoint of supply chain coordination mechanism, there is a lack of effective collaborative decision-making mechanism between suppliers and e-commerce retailers. This is manifested in the following ways: (1) the two sides work on their own and make profit maximization decisions independently; (2) they have not yet established a benefit-sharing cooperation model; and (3) they have failed to form a dynamic strategic alliance to jointly deal with bottlenecks in supply chain management. This non-cooperative game mode of operation further exacerbates the inefficiency of the supply chain system.

Moreover, under the background of the rapid development of the Internet and e-commerce, O2O e-commerce sales are characterized by a high return rate. Based on this, this study

focuses on the return behavior of consumers on downstream e-commerce platforms, focusing on the construction of a systematic return management process and the formulation of a scientific and reasonable return management policy, with a view to achieving the dual goals of optimizing the return cost and improving consumer satisfaction.

3. Pricing Management Optimization Strategy

Aiming at the problem of non-coordination in quantity decisions and pricing strategies of upstream suppliers in the supply chain, this study analyzes it by constructing a Stackelberg game model.

Under the O2O e-commerce model, the supply chain pricing game between a supplier and an e-commerce retailer is studied (As shown in Figure 1). The supplier is able to independently determine the wholesale price of the product, and the e-commerce retailer uses this wholesale price to purchase the product from the supplier, and at the same time independently determines the retail price of the product to be sold. In this process, the supplier is able to observe the decision-making behavior of the e-commerce retailer and is in an advantageous position.

Figure 1. Supply chain structure

It is assumed that each member in the e-commerce supply chain is a rational economic man, who pursues the maximization of his own interests. And keep risk-neutral, with independent decision-making power. Suppliers and e-commerce retailers are fully aware of the benefits of the game for all parties and the game process before they choose. The cost of logistics and transportation and other intermediate links are not considered in this model. The parameters and implications of the modeling are shown in Table 1.

The market demand here uses a general linear demand function, i.e., $Q = a - bp$, where $p > w > 0$.

Table 1. Summary of notations

Parameters	Implications
a	Maximum potential demand of the market
b	The sensitivity coefficient of price with respect to demand
w	Wholesale price of products per unit for supplier
p	E-commerce retailer's selling price per unit of product
s_m	Supplier's cost of supply per unit of product
s_r	E-commerce retailer's selling cost per unit of product
λ	Revenue-sharing ratio
κ	Proportional variable

This leads to a profit function for the supplier as:

$$\pi_m = (a - bp) \cdot (w - s_m)$$

The profit function of the e-commerce retailer is:

$$\pi_r = (a - bp) \cdot (p - w - s_r)$$

The total profit function in the supply chain is:

$$\pi_t = (a - bp) \cdot (p - s_m - s_r)$$

(1) Non-cooperative pricing

That is, a Stackelberg game model is constructed: the supplier is the leader, dominating the wholesale price of the product; the e-commerce retailer is the follower. At the same time, both the supplier and the e-commerce retailer are completely rational individuals, and will pursue their own interests to maximize. The decision-making sequence is divided into two stages and solved by using the reverse induction method. Occupying the leading position of the supplier to maximize their own profits as the goal, first determine the optimal wholesale price per unit, the e-commerce retailers in the follower according to the supplier's proactive strategy, to determine the retail price per unit to meet their own optimization, so that the profit function at this time to achieve the maximum value.

$$\begin{cases} \max\limits_{w_0} \pi_m = (a - bp) \cdot (w - s_m) \\ \max\limits_{p} \pi_r = (a - bp) \cdot (p - w - s_r) \\ s.t. p = \arg\max \pi_r \end{cases}$$

It can be solved for:

$$p = p_r^* = \frac{a + bw + bs_r}{2b}$$

This value satisfies both of the following equations:

$$\frac{d\pi_r}{dp} = (-b) \cdot (p - w - s_r) + a - bp = 0$$

$$\frac{d^2\pi_r}{dp^2} = 0 \cdot (p - w - s_r) + 2 \cdot (-b) < 0$$

In this case, the supplier's profit function is adjusted to:

$$\pi_m = (a - bp_r^*) \cdot (w - s_m) = \frac{(a - bw - bs_r) \cdot (w - s_m)}{2}$$

The first-order derivative of which is made to be zero:

$$\frac{\partial \pi_m}{\partial w} = \frac{1}{2} \cdot (a - 2bw + bs_m - bs_r) = 0$$

It can be solved for:

$$w = w^* = \frac{a + bs_m - bs_r}{2b}$$

Substituting can be obtained:

$$p = p_r^* = \frac{3a + bs_m + bs_r}{4b}$$

In this case, the supplier maximizes the profit as:

$$\pi_m = \frac{(a - bs_m - bs_r)^2}{8b}$$

The e-commerce retailer to maximize profits for:

$$\pi_r = \frac{(a - bs_m - bs_r)^2}{16b}$$

The overall profit of the supply chain is:

$$\pi_c = \pi_m + \pi_r = \frac{3(a - bs_m - bs_r)^2}{16b}$$

(2) Cooperative pricing

With the objective of maximizing the overall revenue of the supply chain to maximize the total profit function in the supply chain, this decision variable needs to be satisfied simultaneously:

$$\frac{d\pi_t}{dp}=(-b)\cdot(p-s_m-s_r)+a-bp=0$$

$$\frac{\mathrm{d}^2\pi_t}{dp^2}=0\cdot(p-s_m-s_r)+2\cdot(-b)<0$$

There exists a unique $p=p^*$ that satisfies both equations above, when the supply chain maximizes profit. It can be formulated:

$$p=p^*=\frac{a+b(s_m+s_r)}{2b}$$

Maximizing profits in the supply chain for:

$$\pi_t(p^*)=\frac{(a-bs_m-bs_r)^2}{4b}$$

The total supply chain benefit obtained from cooperative pricing is more than that from non-cooperative pricing, as proved below:

$$\pi_t(p^*)-\pi_c=\frac{(a-bs_m-bs_r)^2}{16b}>0$$

Thus, the overall profit of the supply chain in the cooperative pricing mode will be better than that in the non-cooperative pricing mode. And along with the maturity of supplier's production process and the reduction of e-commerce retailer's selling cost, the profit gap between the two will be bigger.

In order to maintain the stability of O2O e-commerce supply chain as a whole, e-commerce retailers should take the initiative to strengthen cooperation with suppliers, and jointly develop effective and reasonable constraints to maximize the benefits of the supply chain as a whole under the condition that their respective benefits will not be lower than the non-cooperative pricing game.

In this paper, a revenue-sharing contract is introduced to appropriately weaken the dominant position of the supplier and increase the enthusiasm of the e-commerce retailer in the case of cooperative pricing. That is, the supplier wholesales flowers to the e-commerce retailer at a lower price, but the e-commerce retailer will bear a certain proportion of the revenue sharing coefficient λ, which ultimately makes the profits of both parties increase, and achieves the effect of win-win cooperation. Due to the consideration of the instability of the product sales flow of the O2O e-commerce platform in reality, the supplier will adjust the revenue sharing coefficient at the right time, and after the game and negotiation, the final e-commerce retailer fulfills the proportion of $k\lambda$, and the supplier obtains the proportion of (1-$k\lambda$), where k is a proportional variable, $k\sim N(\mu,\sigma^2)$.

Under this revenue-sharing contract, the profit functions of the supplier and the e-commerce retailer are respectively:

$$\pi_m^{'}=(a-bp)\cdot(w-s_m)+(1-k\lambda)p\cdot(a-bp)$$

$$\pi_r^{'}=(a-bp)\cdot(k\lambda p-w-s_r)$$

Solve for the retail price that satisfies the first and second order conditions of the e-commerce retailer's profit function:

$$p^{'}=\frac{ak\lambda+b(w+s_r)}{2bk\lambda}$$

In order to achieve supply chain optimization and coordination, it is necessary to satisfy:

$$p^{'}=p^*$$

Then there is a coordinated wholesale price:

$$w^{'}=k\lambda s_m-(1-k\lambda)s_r$$

In this case, the profit functions of the supplier and the e-commerce retailer are, respectively:

$$\pi_m^{''}=\frac{(1-k\lambda)\cdot(a-bs_m-bs_r)^2}{4b}$$

$$\pi_r^{''}=\frac{k\lambda(a-bs_m-bs_r)^2}{4b}$$

For both the supplier and the e-commerce retailer to have economic incentives to participate in the optimal coordination and to encourage the two to increase cooperation, it is necessary to satisfy that the benefits of each party after coordination are greater than the benefits of each party under non-cooperative pricing, i.e., $\pi_m^{''}>\pi_m$ and $\pi_r^{''}>\pi_r$, then the benefit-sharing coefficient λ needs to be satisfied:

$$\lambda\in[\frac{1}{4k},\frac{1}{2k}]$$

Therefore, although both the supplier and the e-commerce retailer have egoistic motives, from the perspective of long-term evolution, the e-commerce retailer and its supplier adopt a cooperative pricing strategy in order to meet the goal of maximizing long-term benefits. By setting an appropriate revenue sharing coefficient λ under cooperative pricing, both parties can obtain more revenue than without cooperation, which to a certain extent can encourage suppliers and e-commerce retailers to strengthen cooperation and thus achieve the optimization of supply chain coordination.

4. Returns Management Optimization Strategy

Under the O2O model, the return behavior of consumers can pose a great challenge for the e-commerce retailer, as the return of products needs to take into account the remaining value of the product, the merchant's compensation for the returned product, and the cost of reverse logistics. In order to improve the processing efficiency of the return process and minimize the loss of e-commerce retailers, the types of product returns should first be divided into specific categories:

(1) Returns of defective products: mainly due to product quality, handling or damage during distribution and transportation.

(2) Returns of non-defective products: mainly from reasons such as lack of consumer satisfaction and deviation from expectations.

(3) Returns due to order processing errors: sometimes the e-commerce retailer's operation and management may be deficient, and the relevant personnel may make mistakes in order processing, such as product selection errors.

(4) Returns due to delivery delay: Although supply chain management requires mutual cooperation and trust between each member of the supply chain, delays in supply chain production, transportation, distribution and other links due to other reasons cannot be ruled out, which ultimately lead to delays in the delivery of the products, making consumers ask for returns due to late delivery.

(5) Other types.

Based on the supply chain pricing model in the previous section, the profit function of the e-commerce retailer is known to be:

$$\pi_r=(a-bp)\cdot(p-w-s_r)$$

For different types of returns, without taking into account the labor cost, time cost and other factors in the return and

exchange of goods, the exchange of products and the original order of the same cost of the product, the e-commerce retailer needs to focus on the remaining value of the product j, the merchant's compensation for the returned product θ, and the cost of reverse logistics h.

In order to more intuitively reflect the profit value gap between the various returns strategy, substituting a set of values: Q=10, $w+s_r=6$, j=4, θ=100, h=3, the specific results are shown in Table 2 below:

Table 2. Profit function and profit value under returns modes

Returns mode	Profit function	Profit value
Returns and refunds	$\pi_r-\theta-h+j\cdot Q$	-23
No returns and refunds	$\pi_r-\theta$	-60
Exchanges	$\pi_r-h+(j-w-s_r)\cdot Q$	17
Refuse returns and refuse refunds	π_r	40

Problems in all four strategies should be resolved as much as possible within 24 hours to improve consumer satisfaction while also being able to indirectly reduce supply chain losses. The resulting design of different situations to take different product returns strategy solutions:

(1) Returns and refunds: for defective products, order processing errors, delivery delays and other situations in which consumers require no replacement.

(2) No returns and refunds: the profit is the lowest of the four strategies, generally considered when the reverse logistics costs are greater than the remaining value of the returned product.

(3) Exchanges: is a superior strategy and is recommended for consumers in most cases.

(4) Refuse returns and refuse refunds: used for non-defective products, non-quality issues in the more unreasonable cases such as consumers malicious refund, refused to accept the order.

In reality, the e-commerce retailers not only need to choose appropriate returns strategies in an effort to minimize returns losses, but also need to further strengthen returns management in order to reduce the consumer returns rate of e-commerce sales, and the suggested measures are as follows:

(1) Enhance cooperation within and outside the supply chain. Improve upstream and downstream coordination in the supply chain and integrate business processes[6]. Set up a specialized collaborative department for returns management and adopt different return strategies for different types of returns.

(2) Establish and maintain a proper order management system. Grasp the returns information in its entirety, categorize and record product quality, the quantity and price of the order, delivery speed and many other indicators, while intelligently planning returns routes according to the system and sharing transportation resources in order to save time and reduce wastage, and help e-commerce retailers to better adjust their returns strategy.

(3) Strengthen the management of returns regulations[7]. The e-commerce retailer needs to clearly revise and improve the standardized return guidelines and implementation rules, and strictly implement the guidelines in order to achieve the purpose of saving time and cost.

(4) Strengthen quality management [8]. The e-commerce retailer should endeavor to improve product quality assurance techniques and technology, and strengthen the quality management of each stage in the supply chain

5. Conclusion

This study combines the existing literature research and the real research situation, systematically analyzes the pricing and returns management problems in the supply chain management under the O2O model, and puts forward the targeted optimization strategies, with a view to improving the efficiency of supply chain management and obtaining the competitive advantage in the e-commerce industry. The specific research conclusions are summarized as follows:

(1) In order to improve the pricing problem, cooperative pricing is derived to be superior to uncooperative pricing based on the established Stackelberg model, and the strategy of coordinated pricing is formulated through the revenue-sharing contract model to promote long-term cooperation and maintain the stability of the e-commerce supply chain as a whole.

(2) Considering the large losses incurred by consumers' returns behavior to e-commerce retailers in real life, attention should be paid to the issue of returns management link. The e-commerce retailer needs to divide the types of product returns, design a return strategy program, analyze and compare the impact of four return modes on the optimal profit of the supply chain, and conclude that the exchanges mode is relatively better. On the basis of this solution, some optimization suggestions to strengthen the return management of e-commerce retailers are propose.

This paper has the following research limitations:

(1) There is still a gap between the model established and the actual e-commerce operation. In the process of establishing the model, some minor factors and factors that can not be taken into account for the time being are discarded, so there is still a certain gap with the actual O2O e-commerce business model operation.

(2) The supply chain data research is still insufficient. The research information and the existing market public data and literature are not enough to cope with the dynamic changes and development of the market.

The following directions can be investigated further in the future:

(1) The social economy is constantly developing, the competition in various industries has intensified, and the e-commerce enterprises will be eliminated by the market with a high probability if they only rely on their own strength and don't share the work with other enterprises. Therefore, under the dynamic market environment, it is also a hot direction to study the competition and cooperation of the node enterprises in the supply chain.

(2) This research just consists of a supplier and an e-commerce retailer in the supply chain model, in the complex actual market environment, the future study of one-to-many, many-to-one, many-to-many supply chain management optimization problems, is very practical reference value.

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