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Research on Member Decision-making of Dual-channel Supply Chain with TPL Participation

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Abstract: With the development of the Internet, more and more enterprises choose the dual-channel supply chain for the sale of goods, in which the third-party logistics service provider plays an important role. By adopting the modified hotelling model, this paper constructs a three-level two-channel supply chain model, discusses the influence of centralized and decentralized decision-making on the decision-making of supply chain members, and puts forward corresponding management suggestions.

Keywords: TPL; Dual-channel supply chain; Logistics service value; Modified Hotelling model.

1. Introduction

At present, affected by the epidemic, online retail has become the mainstream of the consumer market, and many enterprises have begun to turn to online sales to meet consumers' shopping needs. The rise of e-commerce and increased consumer demand for diverse, personalized products have also prompted companies not to explore more flexible sales models. Online shopping has become an important way of shopping for consumers, many consumers through online channels buy goods, but also buy goods through offline channels. Traditional supply chains are built offline and cannot fully meet the need to adopt lines,in order to meet the needs of consumers who buy goods through channels, enterprises must organically integrate online and offline channels are bound together. In the retail industry, major supermarkets and shopping malls have established online and offline dual-channel sales models, consumers can.To buy goods through the online platform, you can also go to the physical store to buy goods. Therefore, actively exploring the dual-channel supply chain with the participation of logistics service providers is of great significance for the long-term healthy development of the supply chain

2. Literature References

At present, the literature on dual-channel supply chain decision-making at home and abroad mostly considers the behavior factors of members and consumers in supply chain decision-making behavioral or social behavioral factors. Zhou [1] et al. studied the dual-channel closed-loop supply chain of retailers with fairness concern behavior, and analyzed the impact of retailers' fairness concern behavior on the decision-making and coordination of the supply chain system. Yu[2] et al. studied the ordering decision and coordination problem of two-level dual-channel supply chain with different entities considering fairness concerns under three circumstances. Xie[3] et al. analyzed the decision-making of the fresh supply chain system of retailers' dual-channel, suppliers' dual-channel and mixed dual-channel, and conducted decision-making research on consumers' preference for low-carbon fresh in different channels, which provided certain enlightenments to the decision-making members of the fresh dual-channel supply chain. Li[4] et al. built two different contracts to coordinate decision-making behaviors among supply chain members according to the coefficient of CSR undertaken by manufacturers. Zhang[5] et al. studied the impact of social responsibility activities of supply chain members on the overall activities of supply chain and the carbon emission and energy saving of enterprises under different carbon regulatory policies.

Supply chain research considering third-party logistics service providers is mainly focused on retail closed-loop supply chain, fresh agriculture supply chain, recycling reverse supply chain and cross-border e-commerce supply chain. Chen [6] et al. studied member decision-making in the three-level closed-loop supply chain composed of manufacturers, retailers and third-party logistics providers, and analyzed the impact of market demand, price sensitivity and logistics cost on member decision-making. Rabbani[7] et al. considered the remanufacturing closed-loop supply chain model composed of manufacturers, distributors and third-party logistics providers to study whether remanufacturing technology research and development should be carried out to reduce the adverse utility of the supply chain.Li [8] et al. proposed a three-level FAP agricultural product supply chain composed of FAP suppliers, logistics service providers and large e-commerce platforms, and established a supply chain decision-making and coordination model under the principal-agent contract by considering the three situations of logistics time-space cost and product freshness. Luo[9] et al. established a three-level supply chain of retailers, suppliers and third-party logistics service providers, studied the impact of temperature control and demand for fresh agricultural products on product freshness, and proposed a contract coordination mechanism of cost sharing and fixed compensation. Li[10] et al. established a closed-loop remanufacturing supply chain composed of original equipment manufacturers, logistics providers and remanufacturers, analyzed the influence of different service levels and government subsidies on supply chain decision-making, and solved the problem of optimal decision-making of supply chain members under government subsidies.Hu[11] et al. established a supply chain composed of overseas manufacturers, domestic suppliers and third-party integrated international logistics service providers, analyzed the impact of income and cost sharing on the three-level decentralized decision-making supply chain, and provided inspiration from the perspective of how cross-border e-commerce practitioners can effectively cooperate and coordinate in global trade.

3. Model

3.1. Symbolic specification and model assumptions

This chapter constructs a three-level dual-channel supply chain system composed of manufacturers, TPL, online platforms, offline retailers and consumers. Among them, part of the products produced by the manufacturer are sold by retailers through offline traditional direct sales, and the other part is sold through online platforms. All logistics activities in the system are provided by the same third-party logistics service provider, and the online platform and offline retailers bear their own logistics service costs. Online platforms and offline retailers sell products at different prices.The symbols and descriptions required in this section are shown in Table 1 below:

Table 1. Symbols and meanings

Symbols	Meanings
V	The total utility value of the product to the customer
t	Unit distance cost
l	Distance from the online platform to the consumer
f	Differences between offline platforms and offline retail channels
μ	Service cost coefficient of logistics service value
c_m	Manufacturer's unit cost of production
c_l	Unit logistics cost of third-party logistics service provider

In order to facilitate the follow-up study, the following hypothesis is first made:

Hypothesis 1: Assuming that the market demand is consistent with the production output, considering the characteristics of the dual-channel supply chain, the online and offline market share will be affected by different circumstances. If the traditional model assumes that the market size is inelastic, it may lead to an unlimited increase in the sales price. Therefore, the revised model is used to describe the market share.Based on the revised model under the dual-channel model, the market demand of online platform and offline retailer are $d_o = \frac{2V+p_t-3(p_o-e)+tf}{2t}$、$d_t = \frac{2V+p_o-e-3p_t+tf}{2t}$.

Hypothesis 2: the entire customer demand market is represented as a straight line. Suppose that there is an undifferentiated product in this market, but the price is different in different sales channels, but the manufacturing cost of the product is the same.

Hypothesis 3: Logistics service providers provide all logistics activities of the entire supply chain and bear all logistics costs, among which the logistics costs are borne by online platforms and offline retailers respectively.

Hypothesis 4: In this supply chain, the manufacturer is in a dominant position when making decentralized decisions, and the decision is made by game. All members of the supply chain are completely rational, and all members are fully information-sharing and risk-neutral.

3.2. Hotelling requirements characterization

Since the traditional model assumes that the market size is inelastic, which may lead to an unlimited increase in sales price, this paper, referring to the construction logic of the revised model, combined with the characteristics of the dual-channel supply chain, assumes that in a straight line space, online platforms and offline retailers are distributed at both ends of the line, selling products with different prices, and consumers are evenly distributed along the line. Represents the difference between the online platform and the offline retailer sales products, the smaller the difference of the product, the stronger the fungibility, and vice versa.

Considering the characteristics of the dual-channel supply chain, the revised distance between the middle consumer and the online platform is l, and the unit cost of the distance is t, and the online platform can obtain the value of the end-logistics service provided by the logistics service provider. Therefore, the actual price is $p_o - e$, and the price of the offline retailer is p_t.

Therefore, the market demand of online platform and offline retailer based on the revised model under the dual-channel model are

$$d_o = \frac{2V + p_t - 3(p_o - e) + tf}{2t}$$

$$d_t = \frac{2V + p_o - e - 3p_t + tf}{2t}$$

3.3. Centralized decision

In the three-level dual-channel supply chain considered in this paper, the revenue obtained by the manufacturer consists of the wholesale revenue of the online platform and the revenue of the traditional retail channel paid by the offline retailer. The revenue of the retailer is the retail revenue of the traditional retail channel, and the revenue of the online platform is the sales revenue of the online channel. It is also necessary to pay the respective logistics costs to the third-party logistics service provider. The third-party logistics service provider undertakes logistics activities in the entire supply chain, and its income mainly comes from the logistics expenses paid by offline retailers and online platforms, but it needs to bear the operating costs of the online platform that bring benefits due to the value of end-logistics services, whose unit costs are the same across different channels. In this case, the profit functions of the supply chain members are as follows:

$$\pi_m = (w - c_m)(d_t + d_o) = \frac{(w-c_m)(2V-p_o-p_t+e+tf)}{t} \quad (1)$$

$$\pi_l = (p_l - c_l)(d_o + d_t) - \frac{\mu e^2}{2} = \frac{(p_l-c_l)(2V-p_o-p_t+e+tf)}{t} - \frac{\mu e^2}{2} \quad (2)$$

$$\pi_o = (p_o - w - p_l)d_o = \frac{(p_o-w-p_l)(2V+p_t-3(p_o-e)+tf)}{2t} \quad (3)$$

$$\pi_t = (p_t - w - p_l)d_t = \frac{(p_t-w-p_l)(2V+p_o-e-3p_t+tf)}{2t} \quad (4)$$

In a centralized decision-making supply chain model, The overall profit of the supply chain is:

$$\pi = \pi_m + \pi_l + \pi_o + \pi_t \quad (5)$$

At this time, the game decision order of the dual-channel supply chain is as follows: the manufacturer, the third-party logistics service provider, the online platform and the offline retailer as a whole simultaneously determine the online platform sales price, the offline retail price and the logistics service value based on the Nash game.

Under centralized decision-making, the optimal sales price of online platform, the optimal retail price of offline platform and the optimal logistics service value are

$$p_o^* = \frac{(2V + tf - 2(c_l + c_m))(4\mu t - 1)}{4(4\mu t - 3)} + c_l + c_m$$

$$p_t^* = \frac{2V + 2(c_l + c_m) + tf}{4}$$

$$e^* = \frac{2V - 2(c_l + c_m) + tf}{4\mu t - 3}$$

Under centralized decision-making, the market share of the online platform channel, the market share of the traditional retail channel and the total profit of the supply chain are

$$d_o^* = \frac{\mu(2V - 2(c_l + c_m)_l + tf)}{4\mu t - 3}$$

$$d_t^* = \frac{(\mu t - 1)(2V - 2(c_l + c_m)_l + tf)}{t(4\mu t - 3)}$$

$$\pi^* = \frac{(2\mu t - 1)(2V - 2(c_l + c_m)_l + tf)^2}{4t(4\mu t - 3)}$$

3.4. Decentralized decision

In the decentralized decision-making model, manufacturers, third-party logistics service providers, online platforms and offline retailers make decisions as independent individuals, each with the goal of maximizing their own profits. As the supplier of products, the manufacturer is responsible for supplying the products of the platform and offline retailers in the dual-channel supply chain, so the manufacturer is often the dominant player in the dual-channel supply chain. In this case, the decision order of the three-level dual-channel supply chain is as follows: The manufacturer determines the wholesale price according to the market situation, and the third-party retailer sets its own logistics price and logistics service value after observing the manufacturer's wholesale price. The online platform and offline retailer determine their own online sales price and offline retail price through the Nash equilibrium according to the decision of the manufacturer and the third-party logistics provider.

Under decentralized decision-making, the optimal wholesale price of manufacturers, the optimal logistics price of third-party logistics service providers, the optimal logistics service value, the optimal sales price of online platforms, and the optimal retail price of offline retailers are

$$w^{**} = \frac{2V - 2c_l + 2c_m + tf}{4}$$

$$p_l^{**} = \frac{5\mu t(2V + tf + 6c_l - 2c_m) - 6c_l}{40\mu t - 6}$$

$$e^{**} = \frac{3(2V - 2(c_l + c_m) + tf)}{40\mu t - 6}$$

$$p_o^{**} = \frac{(2V + tf - 2(c_l + c_m))(238\mu t - 9)}{28(20\mu t - 3)} + c_l + c_m$$

$$p_t^{**} = \frac{(2V + tf - 2(c_l + c_m))(238\mu t - 33)}{28(20\mu t - 3)} + c_l + c_m$$

Under decentralized decision-making, the market share of online platform, the market share of traditional retail channels, and the total profit of supply chain are

$$d_o^{**} = \frac{3(7\mu t + 3)(2V - 2(c_l + c_m) + tf)}{14t(20\mu t - 3)}$$

$$d_t^{**} = \frac{3(7\mu t - 3)(2V - 2(c_l + c_m) + tf)}{14t(20\mu t - 3)}$$

$$\pi^{**} = \frac{3(3332(\mu t)^2 - 441\mu t + 72)(2V - 2(c_l + c_m)_l + tf)^2}{392t(20\mu t - 3)^2}$$

4. Comparative Analysis

Proposition 1 The value of logistics service under decentralized decision-making is lower than that under cooperative decision-making, namely $e^{**} < e^*$.

Proposition 1 shows that under centralized decision-making, comprehensive resource allocation is often carried out to form scale effects, so as to reduce unnecessary waste and enhance the value of terminal logistics services. Therefore, from the perspective of logistics service value, centralized decision-making is better than decentralized decision-making.

Proposition 2 The offline retail price of decentralized decision-making is greater than that of centralized decision-making, namely $p_t^* < p_t^{**}$.If $\frac{3}{4t} < \mu \le \frac{521}{392t}$, then $p_o^* \ge p_o^{**}$; If $\mu > \frac{521}{392t}$, then $p_o^* < p_o^{**}$.

Proposition 2 shows that in the decentralized decision-making mode, as each member pursues its own profit maximization, offline retailers will choose to increase their own sales prices to obtain higher profits when all costs remain unchanged. For online platforms, when the value cost of logistics service is too high, it is difficult for them to enjoy the extra profits brought by the value of logistics service. In order to maintain their own profits, they have to increase the sales price. Although online platforms and offline retailers can obtain higher profits from a unit of goods in the short term, since consumers tend to obtain products at higher prices, in the long run, high prices will make consumers lose their desire to buy, resulting in greater losses of profits.

Proposition 3 The market share of online platforms with decentralized decision-making is smaller than that of online platforms with centralized decision-making,namely $d_t^* > d_t^{**}$.If $\frac{3}{4t} < \mu < \frac{209}{196t}$, then $d_t^* < d_t^{**}$; If $\mu > \frac{209}{196t}$, then $d_t^* > d_t^{**}$.

Proposition 3 shows that under normal circumstances, under centralized decision-making, supply chain members can enable enterprises to better allocate resources, gain economies of scale, and continuously expand online and offline market share. However, under decentralized decision-making, supply chain members, aiming at maximizing their own profits, will constantly increase their own prices, which will cause consumers to lose their desire to buy products, thus reducing their purchase demand. Online and offline market share decreases, but when the cost is relatively small, for offline retailers, decentralized decision-making seeks to maximize its own profit, so its market share will be larger than centralized decision-making. Therefore, when the value cost of logistics service is relatively small, offline retailers will make choices inconsistent with the online platform, and it is difficult to reach a consistent decision. But in general, centralized decision making is better.

Proposition 4 The total profit of the supply chain under centralized decision-making is greater than that under decentralized decision-making, namely $\pi^{**} < \pi^*$.

Proposition 4 shows that the total profit of the supply chain increases due to the decrease of online platform sales price and offline retail price and the increase of logistics service value under centralized decision-making. Therefore, from the perspective of profit, centralized decision-making is better than decentralized decision-making.

5. Summary

From the perspective of total profit and logistics service value, centralized decision-making is always better than decentralized decision-making, and logistics service value cost has different effects on sales price and market share under different decision-making modes. For online platforms, when the value cost of logistics services is small, the price of centralized decision-making is higher than that of decentralized decision-making; when the value cost of logistics services is large, the price of centralized decision-making is lower than that of decentralized decision-making; and the market share of online platforms in centralized decision-making is always higher than that in decentralized decision-making. For offline retailers, the retail price of centralized decision-making is always lower than that of decentralized decision-making, and when the value cost of logistics services is small, the market share of centralized decision-making is lower than that of decentralized decision-making, and when the value cost of logistics services is large, the market share of centralized decision-making is higher than that of decentralized decision-making. This shows that although decentralized decision-making has some advantages when the value cost of logistics services is relatively small, it is still not superior to centralized decision-making in general. Therefore, members of the supply chain can reach a certain contractual relationship, actively seek cooperation, and reduce the retail price of products, thus promoting the increase of demand in various channels and ultimately improving the total profit of the supply chain.Although this paper has made some contributions to the decision-making of the members of the three-level dual-channel supply chain, it also has some shortcomings on the whole, and the follow-up research direction can be further expanded. First of all, although this paper adopts the modified Hotelling model to describe the market demand, it is still a linear function without considering the randomness of the market demand.

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