A Research on Brand-enabled Supply Chain Decision-making in Fresh Produce E-commerce Platforms

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Abstract: Under the influence of market demand fluctuation, the difference in the quality of the source of goods of risk-averse retailers leads to the problem of profit damage between the two parties of empowerment co-operation. Based on this, this paper establishes a Stackelberg game model for the brand empowerment supply chain of fresh food e-commerce platform with vertical channel conflict. From the supply chain perspective, we explore the impact of brand empowerment level, risk sharing coefficient, order quantity of different channels and other factors on the decision-making of the two co-operating parties under different empowerment contracts. The study finds that (1) fresh food e-commerce companies can reduce the damage of other channels' products to the platform's brand value through risk-sharing strategies. (2) Differentiated empowerment pacts for different types of retailers can effectively mitigate channel conflicts and increase fresh food e-commerce companies' profits.

Keywords: Fresh Food E-Commerce; Brand Empowerment; Risk Aversion; Channel Conflict

1. Introduction

On the basis of network technology and intelligent logistics drive, the fresh food e-commerce industry to achieve online and offline integration and development, the rapid rise. From the perspective of offline retailers, it is found that there is extreme uncertainty in the retail market, which makes the risk-averse attributes of retailers prominent and leads to biased decisions. And the difference between interest target and positioning decision in platform-enabled cooperation can be one of the factors of channel conflict[1]. Freshippo, as a representative of new retailing, provides consumers with convenient services of high-quality fresh ingredients, but there were incidents of "rotten apple juice" and "expired coconut milk", etc. Complaints about fake products from Tmall Mart and Lifease are also increasing. The problem has also been aggravated. The inflow of low-quality products from other channel suppliers is highly correlated with the retailer's risk-averse tendency to influence decisions on both sides of the brand empowerment partnership. On this basis, platform-based e-commerce companies need to consider how to establish a benign cooperation model under the changing decision-making tendencies of retailers and promote a virtuous cycle of brand-empowered supply chains. The cooperation between platform-based e-commerce enterprises and offline retailers has various problems such as brand empowerment, risk sharing, and product channel damage. Therefore, under the uncertain market demand, how to design a suitable empowerment contract to alleviate the channel conflict in the process of brand empowerment and realize the value co-creation between the two sides is an urgent issue to be solved[2].

With the increasing industry status of e-commerce enterprises, many scholars have conducted in-depth research on the supply chain centered on platform-based e-commerce enterprises. Literature[3-5] conducts research on decision coordination and profit sharing strategies for channel conflict and member profit dichotomy problems within different supply chain structures. Other scholars have studied the process model of platform enterprise empowerment for value co-creation, in which the game analysis of paid data empowerment cooperation is conducted[6,7].Xiao D et al.[8]analysed the mechanism of platform-based e-commerce enterprises' brand empowerment behaviours and differentiated product strategies on vertical channel conflict and supply chain synergistic merchants, in which the loss of goodwill is regarded as a decision-making influencing factor. Zhang et al.[9], for a dual-channel supply chain with quality differences, modelled the sensitivity of production cost and consumer demand to product quality level. Literature[10-12] analyses the impact of quality differentiation in supply chains on the pricing of supply chain members' products, heterogeneous quality-sensitive customer groups, and channel cannibalisation. In addition, some scholars have studied the impact of quality constraint effects and quality sensitivity parameters on price and product quality, as well as profit and consumer surplus without using market structure[13,14].

In summary, it can be found that: (1) the current research on empowerment behaviours in the supply chain of fresh food e-commerce enterprises is mostly focused on big data empowerment, while few scholars have conducted research on the brand empowerment of fresh food e-commerce platforms for retailer cooperation. (2) The impact analysis between retailers' risk aversion and platform's goodwill loss under market volatility is ignored in the research on channel conflict in platform's empowerment cooperation. Unlike previous studies, the innovative starting points of this study include: Considering platform-based e-commerce enterprises as suppliers, and highlighting their empowerment level and product high-quality characteristics as research points. Based on the mean-variance method and other methods, we draw the equilibrium solutions of decision factors under different platform empowerment strategies, and explore the influence of empowerment strategies on retailers' order quantities in different channels.

2. Problem Description and Assumptions

2.1 Problem Description

In this paper, we consider a supply chain consisting of platform-based e-commerce enterprises, retailers, and other channel suppliers, with retailers buying from platform-based e-commerce enterprises and other channel suppliers, with purchase prices of ω_p and ω_i .Among them, the incoming procurement cost of platform-based e-commerce enterprises and the production cost of other channel suppliers are not considered decision-influencing factors. Retailers order products from platform-based e-commerce companies and other channel suppliers, with q_p and q_s being the order lot, and sell at the retail price of p_q and p_s .See figure 1 for the above.

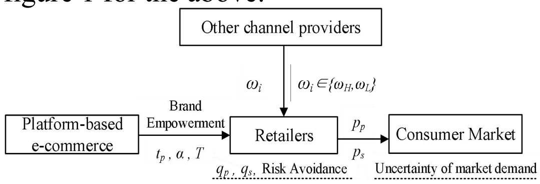

Figure 1. Supply Chain Decision Diagram

2.2 Symbol Definitions and Assumptions

The meanings of other parameters and variables in the text are shown in Table 1.

Table 1. Symbols and Symbol Descriptions

Symbol	Symbol Description
w_p	Platform-based e-commerce supply prices to retailers
w_i	Supply price of other channel suppliers
q_i	Retailers' order volume by different channels, $i\in[p,s]$
p_i	Retailer differential product sales prices, $i\in[p,s]$
λ	Product quality defect probability for L-type retailers
ρ	The probability that the retailer is an H-type
a	Retention price of the product
β	Degree of product replacement
g	Brand Competence
γ	Brand CompetenceThe degree of product price response to g
θ	Max.value of g
η	Level of Brand Empowerment
T	Cost-Sharing Funds
d	Empowerment Cost modulus
α	Risk sharing factor
k_t	Retailer risk avoidance factor

This paper makes the following assumptions. Consider a risk-averse retailer and a risk-neutral platform provider. Mean-variance methodis used to measure the level of risk aversion of the retailer. The characteristics are measured by a mean-variance function with an expected utility function of $E(U_t(\pi_t)) = E(\pi_t) - k_t\sqrt{Var(\pi_t)}$, k_t ($k_t > 0$) is the degree of risk aversion of the retailer, $0 \le k_t \le 1$,The larger the k_t , the greater the risk aversion of the retailer. In this paper, the inverse demand function form is used to describe the order quantity of retailers in the platform-based e-commerce channel and other ordering channels when considering the uncertainty of market demand:

1) $p_p = a - q_p - \beta q_s + \varepsilon + \gamma g$;

2) $p_i = a - q_i - \beta q_p + \varepsilon + \gamma g$.

The a denotes the reservation price of two products, $a > \omega_p$; β denotes the degree of substitution between two products, $\beta \in (0,1]$; ε is a random variable that follows a normal distribution with mean 0 and variance σ^2 .Hypothesis γ indicates the degree of product price response to brand competitiveness; g indicates the retailer's brand competitiveness, $g = \theta\eta$, $g = \theta\eta$, θ indicates the maximum value that can be achieved by the retailer's brand competitiveness, η indicates the level of brand empowerment of retailers by platform-based e-commerce companies, $\eta \in (0,1]$.

That is, the company through its own brand value of the level of empowerment to adjust the brand influence to meet consumer demand, competitiveness to improve and thus obtain high profits.

The difference between the products offered by platform-based e-commerce companies and other retail suppliers exists in price and quality. Platform-based e-commerce companies maintain a high level of product quality through strict incoming screening. As a result, it is assumed that all products of platform-based e-commerce companies are qualified products. The product prices are higher but do not have an impact on the value of the platform-based e-commerce products. Other retail suppliers have lower prices but a certain percentage of substandard products exist. The quality problems of the products ordered by retailers through this channel will have an impact on the product empowerment effect of platform-based e-commerce, and even cause the loss of goodwill of platform-based e-commerce enterprises, where $\omega_p > \omega_i$.

This paper is divided according to the retailer's purchase channel: H-class retailers of other channels suppliers whose product quality level is high, the platform e-commerce enterprises no brand value loss; L-class retailers of other channels suppliers whose product quality level is low, a single product has the λ probability of quality problems and the c_L loss caused to the platform e-commerce enterprises. The other channel retail supplier price ω_i is divided into two categories: ω_H denotes the retailer's purchase price from other retail suppliers with a higher level of quality and ω_L denotes the retailer's purchase price from other retail suppliers with a lower level of quality, i.e. $\omega_S \in \{\omega_H, \omega_L\}$ and $\omega_H > \omega_L$ .Platform-based e-commerce companies have a certain information base on retailers as the dominant supply chain player and can define the type of retailer through data such as the platform complaint rate.

Platform-based e-merchants need to make decisions about the level of brand empowerment, and η indicates the level of brand empowerment of platform-based e-merchants to retailers, $\eta \in (0,1]$ .The cost function of brand empowerment of goods by platform-based e-commerce firms is $d\eta^2/2$, where d is the cost factor and $d > 0$ .The cost incurred by the platform in reaching empowerment level η is $d\eta^2/2$ .Also, assume that the parameter condition $d(1+\beta) > \theta^2\gamma^2$.

Platform-based e-commerce and retailers have an interdependent offline sales partnership. The platform-based e-merchant as the dominant player sets incentives for: first, charging retailers a brand cost-sharing fund of T. Considering the pricing and quality requirements of retailers working with branded e-merchants can exacerbate their risk-averse behavior. So the risk-sharing amount is given to the retailer and set to subsidize the compensation per unit α based on the total amount of products ordered by the retailer. In addition, this paper assumes that the retailer will accept the contract only when the incentive gives the retailer more profit than its retained profit M, without loss of generality.

3. Model Construction and Analysis

The platform-based e-commerce enterprise acts as the dominant player in the supply chain. The platform-based e-commerce enterprise first makes the empowerment contract and makes decisions on η, T, and α. Next, the risk-averse retailer chooses whether to accept the empowerment contract and responds with q_{pi} and q_{si} after accepting the cooperation; finally, the retailer sells the products ordered by the platform-based e-commerce enterprise and the products of other channels to consumers with p_{pi} and p_{si} respectively.

3.1 N Strategy

Under the N-strategy, platform-based e-commerce companies empower retailers with brands and charge a certain amount of margin. At this point, the retailer's profit is:

$$R(N,i) = (p_{pi} - \omega_p)q_{pi} + (p_{si} - \omega_i)q_{si} - T \quad (1)$$

The retailer expected utility function is:

$$E(U_N(\pi_i)) = (a - q_{pi} - \beta q_{si} + \gamma g - \omega_p)q_{pi} + (a - q_{si} - \beta q_{pi} + \gamma g - \omega_i)q_{si} - k_t\sigma(q_{pi} + q_{si}) - T \quad (2)$$

Platform-based e-commerce profit function is:

$$\max_{t_p,T,\alpha} \Pi_N = \rho(\omega_p q_{pH} - \frac{1}{2}d\eta_n^2 + T) + \overline{\rho}(\omega_p q_{pL} - \frac{1}{2}d\eta_n^2 - \lambda c_L q_{sL} + T) \quad (3)$$

By finding the first-order derivatives of q_{pi}^N, and q_{si}^N for equation (2) and solving for them jointly, obtain;

$$q_{pi}^P = \frac{(1-\beta)(a + \theta\gamma\eta_n - \sigma k_t) + \beta\omega_i - \omega_p}{2(1-\beta^2)} \quad (4)$$

$$q_{si}^P = \frac{(1-\beta)(a + \theta\gamma\eta_n - \sigma k_t - \omega_p) + \omega_p - \omega_i}{2(1-\beta^2)} \quad (5)$$

Substituting (4), (5) into (2) and deriving ω gives;

$$\frac{(\beta-1)(\sigma k_t - \theta\gamma\eta_n - a) - \omega_i + \beta\omega_p}{2(\beta^2-1)} > 0$$

$\partial E(U_N(\pi_i))/\partial\omega_i > 0$,.Since platform-based e-commerce firms follow the profit maximization principle when deciding on variable T .To discipline platform-based e-commerce companies and prioritize profits for H type retailers $E(U_N(\pi_H)) > 0$ .we order to take the extreme value of T , i.e., $\omega_i = \omega_H$ [8].

$$T = (a - q_{pH} - \beta q_{sH} + \gamma g - \omega_p)q_{pH} + (a - q_{sH} - \beta q_{pH} + \gamma g - \omega_H)q_{sH} - k_t\sigma(q_{pH} + q_{sH}) \quad (6)$$

Eq.(6) is substituted into Eq.(3) to solve for the platform-based e-commerce enterprise decision η by the inverse order solution method. When $\partial^2\Pi_N/\partial\eta^2 = (\theta^2\gamma^2/1-\beta) - d < 0$, the profit function of platform-based e-commerce firms is a concave function of η and there exists an optimal value.

Rectify the substitution can be obtained:

$$\eta_N^* = \frac{\theta\gamma(2a + \lambda c_L(\rho-1) - 2\sigma k_t - \omega_H)}{2(d + d\beta - \theta^2\gamma^2)} \quad (7)$$

Eq.(4) (5) (7) can be substituted into (6) to obtain;

$$\mathrm{T} = \frac{1}{4(\beta^2-1)}[2(\beta-1)((a - \sigma k_t + \theta\gamma\eta^{N*})(a - \sigma k_t + \theta\gamma\eta^{N*} - \omega_p - \omega_H)) - \omega_p^2 - \omega_H^2 + 2\beta\omega_p\omega_H \quad (8)$$

Eq.(7) can be substituted into (4) (5) to obtain two types of retailer order quantity functions as;

$$q_{\mathrm{pH}}^N = A + 2B(\omega_P - \beta\omega_H)/4\mathrm{B}(\beta^2-1) \quad (9)$$

$$q_{\mathrm{sH}}^N = A + 2B(\omega_H - \beta\omega_P)/4\mathrm{B}(\beta^2-1) \quad (10)$$

$$q_{\mathrm{pL}}^N = A + 2B(\omega_P - \beta\omega_L)/4\mathrm{B}(\beta^2-1) \quad (11)$$

$$q_{\mathrm{sL}}^N = A + 2B(\omega_L - \beta\omega_P)/4\mathrm{B}(\beta^2-1) \quad (12)$$

$$A = 2d(\beta^2-1)(a - \sigma k_t) + \theta^2\gamma^2(1-\beta)(\overline{\rho}\lambda c_L + \omega_H) \quad (13)$$

$$B = d + d\beta - \theta^2\gamma^2 \quad (14)$$

3.2 E Strategy

Platform-based e-commerce companies under the E strategy provide the same risk-sharing policy for both types of retailers while performing brand empowerment and collecting margin, i.e.setting α and T.

The retailer profit function is

$$R(E,i) = (p_{pi} - \omega_p)q_{pi} + (p_{si} - \omega_i)q_{si} + \alpha q_{pi} - T \quad (15)$$

The expected utility function under retailer risk aversion is:

$$E(U_E(\pi_i)) = (a - q_{pi} - \beta q_{si} + \gamma g - \omega_p)q_{pi} + (a - q_{si} - \beta q_{pi} + \gamma g - \omega_i)q_{si} - k_t\sigma(q_{pi} + q_{si}) + \alpha q_{pi} - T \quad (16)$$

The platform provider model is as follows:

$$\max_{\eta,T,\alpha} \Pi_E = \rho(\omega_p q_{pH} - \alpha q_{pH} - \frac{1}{2}d\eta^2 + T) + \overline{\rho}(\omega_p q_{pL} - \alpha q_{pL} - \frac{1}{2}d\eta^2 - \lambda c_L q_{sL} + T) \quad (17)$$

The constraint is to guarantee the profit $E(U_E(\pi_H^e)) > 0$ for H-type retailers under the empowerment contract. For T setting the value limit in the range we get:

$$T = (a - q_{pH} - \beta q_{sH} + \gamma g - \omega_p)q_{pH} + (a - q_{sH} - \beta q_{pH} + \gamma g - \omega_H)q_{sH} + \alpha_e q_{pH} - k_t\sigma(q_{pH} + q_{sH}) \quad (18)$$

The derivative of Eq.(16) concerning q_{pi}^E, and q_{si}^E, respectively, is given by the union:

$$q_{pi}^E = \frac{(1-\beta)(a+\gamma\theta\eta-\sigma k_t)+\alpha+\beta\omega_i-\omega_p}{2(1-\beta^2)} \quad (19)$$

$$q_{si}^E = \frac{(1-\beta)(a+\gamma\theta\eta-\sigma k_t)+\beta(\omega_p-\alpha)-\omega_i}{2(1-\beta^2)} \quad (20)$$

Eq.(18) is substituted into (17) for Π_E to obtain the second order derivatives of η and α.

$$\partial^2 \Pi_E / \partial\eta^2 = \theta^2\gamma^2 - d(1+\beta)/1+\beta < 0 \quad (21)$$

$$\partial^2 \Pi_E / \partial\alpha^2 = 1/2(\beta^2 - 1) < 0 \quad (22)$$

$$\partial^2 \Pi_E / \partial\eta\partial\alpha = \partial^2 \Pi_E / \partial\alpha\partial\eta = 0 \quad (23)$$

The Hesse matrix negative definite can be obtained. Π_E is a concave function with respect to η, α .Further, the optimal decision of brand empowerment level and risk sharing factor can be found.

$$\eta_E^* = \frac{\theta\gamma(2a+\lambda c_L(\rho-1)-2\sigma k_t-\omega_H)}{2(d+d\beta-\theta^2\gamma^2)} \quad (24)$$

$$\alpha_E^* = \omega_p + \overline{\rho}\beta(\lambda c_L + \omega_H - \omega_L) \quad (25)$$

$$T = \frac{1}{4(1-\beta^2)}[2(\beta-1)\sigma^2 k_t^2 + 2(1-\beta)(a+\theta\gamma\eta_p^{P*})(a+\alpha^* + \theta\gamma\eta_p^{P*} - \omega_p - \omega_H) - (\alpha^* - \omega_p)(\omega_p - \alpha^* - 2\beta\omega_H) + \omega_H^2] \quad (26)$$

Eq.(24)(25) is substituted into (19)(20) to obtain the order quantity function for the two types of retailers as :

$$q_{\text{pH}}^E = \frac{A+2\beta B(\overline{\rho}(\omega_L-\omega_H-\lambda c_L)-\omega_H)}{4\text{B}(\beta^2-1)} \quad (27)$$

$$q_{\text{pL}}^E = \frac{A+2\beta B(\overline{\rho}(\omega_L-\omega_H-\lambda c_L)-\omega_L)}{2\text{B}(\beta^2-1)} \quad (28)$$

$$q_{\text{sH}}^E = \frac{A-2B(\overline{\rho}\beta^2(\omega_L-\omega_H-\lambda c_L)-\omega_H)}{4\text{B}(\beta^2-1)} \quad (29)$$

$$q_{\text{sL}}^E = \frac{A-2B(\overline{\rho}\beta^2(\omega_L-\omega_H-\lambda c_L)-\omega_L)}{4\text{B}(\beta^2-1)} \quad (30)$$

3.3 S-Strategy

S strategy under the platform-based e-commerce companies in the brand empowerment at the same time, for the different types of retailers, to implement different empowerment strategies, namely $\alpha \in \{\alpha_H, \alpha_L\}$, $T \in \{T_H, T_L\}$.

The retailer profit function and the expected utility function are as follows:

$$R(S,i) = (p_{pi} - \omega_p)q_{pi} + (p_{si} - \omega_i)q_{si} + \alpha_i q_{pi} - T_i \quad (31)$$

$$E(U_S(\pi_S^e)) = (a - q_{pi} - \beta q_{si} + \gamma g - \omega_p)q_{pi} + (a - q_{si} - \beta q_{pi} + \gamma g - \omega_i)q_{si} - \sigma k_t(q_{pi} + q_{si}) + \alpha_i q_{pi} - T_i \quad (32)$$

The profit function of platform-based e-commerce enterprises is as follows:

$$\max_{t_p,T,\alpha} \Pi_S = \rho[\omega_p q_{pH} - \alpha_H q_{pH} - \frac{1}{2}d\eta_S^2 + T_H] + (1-\rho)[\omega_p q_{pL} - \alpha_L q_{pL} - \frac{1}{2}d\eta_S^2 - \lambda c_L q_{sL} + T_L] \quad (33)$$

Eq.(32) is derived for q_{pi}^S, q_{si}^S respectively and then combined to obtain:

$$q_{pi}^S = \frac{(1-\beta)(a+\theta\gamma\eta_S-\sigma k_t)+\alpha_i+\beta\omega_i-\omega_p}{2(1-\beta^2)} \quad (34)$$

$$q_{si}^S = \frac{(1-\beta)(a+\theta\gamma\eta_S-\sigma k_t)+\beta(\omega_p-\alpha_i)-\omega_i}{2(1-\beta^2)} \quad (35)$$

To ensure the rationality of the differential empowerment contract, profit coordination is required through T,α : ① Guaranteed profit for H-retailers under H-contract, $E(U_S(\pi_H^H)) > 0$ ②Guaranteed profit for L-shaped retailers under L-contracts, $E(U_S(\pi_L^L)) > 0$. ③ Ensure that H-type and L-type retailers have higher profits under their respective contracts: $E(U_S(\pi_H^H)) \geq E(U_S(\pi_H^L))$ $E(U_S(\pi_L^L)) \geq E(U_S(\pi_L^H))$. ④ A higher risk-sharing factor is applied to H retailers, $\alpha_H > \alpha_L$ .Analysis of the constraints yields:

$$T_H = (a - q_{pH} - \beta q_{sH} + \gamma g - \omega_p)q_{pH} + (a - q_{sH} - \beta q_{pH} + \gamma g - \omega_H)q_{sH} + \alpha_H q_{pH} - k_t\sigma(q_{pH} + q_{sH}) \quad (36)$$

$$T_L = T_H + q_{pL}(\alpha_L - \alpha_H)$$

Substitute (34)(35)(36) into (33) to find the second-order derivatives of $\eta_S, \alpha_H, \alpha_L$.

$$\partial^2 \Pi_S / \partial\eta_S^2 = -(d + d\beta - \theta^2\gamma^2)/(1+\beta) < 0 \quad (37)$$

$$\partial^2 \Pi_S / \partial\alpha_H^2 = 2\rho - 1/2(\beta^2 - 1) < 0 \quad (38)$$

$$\partial^2\Pi_s/\partial\alpha_L^2 = 1/2(\beta^2-1) < 0 \quad (39)$$

The $\eta_S, \alpha_H, \alpha_L$ whose optimal decision function can be obtained by the first order derivative equal to zero:

$$\eta^{S*} = \frac{\theta\gamma(2a-\lambda c_L\bar{\rho}-2\sigma k_t-\omega_H)}{2(d+d\beta-\theta^2\gamma^2)} \quad (40)$$

$$\alpha_H^{S*} = (\beta-1)\sigma k_t+\beta\lambda c_L+\omega_p \quad (41)$$

$$\alpha_L^{S*} = \frac{(2\bar{\rho}-1)\beta\lambda c_L}{\bar{\rho}}+\beta(\omega_H-\omega_L)+(\beta-1)\sigma k_t+\omega_p \quad (42)$$

Eqs.(40) to (42) are substituted into (34) (35) to obtain the retailer's order quantity function.

$$q_{\mathrm{pH}}^S = A-2B\beta(\lambda c_L+\omega_H)/4\mathrm{B}(\beta^2-1) \quad (43)$$

$$q_{\mathrm{pL}}^N = 2\beta B(\bar{\rho}(\omega_H+2\lambda c_L)-\lambda c_L)-\bar{\rho}A/4\mathrm{B}\bar{\rho}(1-\beta^2) \quad (44)$$

$$q_{\mathrm{sH}}^S = A+2B((\beta^2-1)\sigma k_t+\beta^2\lambda c_L+\omega_H)/4\mathrm{B}(\beta^2-1) \quad (45)$$

$$q_{\mathrm{sL}}^N = \frac{2B((1-2\bar{\rho})\beta^2 c_L\lambda+\bar{\rho}(1-\beta^2)((\omega_H-\omega_L+\sigma k_t)+\omega_H))-\bar{\rho}A}{4\mathrm{B}\bar{\rho}(1-\beta^2)} \quad (46)$$

4. Numerical Calculation Example

In this section, the theory is analytically verified by using numerical simulations. Drawing on parameter settings from relevant literature, this study assumes:

α=2 , β=0.8 , θ=0.3 , λ=0.1 , c_L=2 , γ=0.15 , d=0.1 , σ=1 , ρ=0.5 , ω_H=0.5 , ω_L=0.4 , ω_p = 0.6 .

4.1Analysis of Retailer's Ordering Strategy

Numerical analysis was conducted for the difference in order quantity of H-type and L-type retailers in different channels under different strategies. As shown in Table 2.

Table 2. H-type and L-type Retailers' Order Quantity by Channel

Variables	N Strategy	E Strategy	S Strategy
q_{pH}	0.1427	1.2426	1.1982
q_{sH}	0.3927	0.3073	0.2017
q_{pL}	0.0316	1.0315	0.9760
q_{sL}	0.5315	0.2684	0.0260

The analysis shows that retailers' ordering decisions tend to increase the proportion of platform channel orders under the S and E strategies compared to the N strategy. The low-price advantage of products in other channels is reduced. The risk-sharing policy adopted by platform-based e-commerce companies in the cooperation contract effectively improves the brand channel loyalty of retailers and alleviates the channel conflict of retailers choosing other channel suppliers due to loss aversion in the cooperation between the two parties.

Among them, the proportion of platform order quantity in the order quantity decision of H-type retailers is the highest in the S-strategy. the incentive strategy under the E-strategy does not differentiate between retailers with different product quality, while the differential sharing strategy under the S-strategy can highlight the advantages of H-type retailers in the platform-empowered cooperation and transfer part of the quality costs through the risk sharing of platform-based e-commerce companies. In addition, the ordering of L-type retailers in both channels under the E strategy is higher than that under the S strategy. The S strategy has the same level of platform empowerment for L-type retailers, but its risk sharing is reduced. The high-risk sharing for L-type retailers under the E strategy increases the order volume of the platform but does not reduce the order volume of other channels, which does not significantly protect the loss of brand value.

For platform-based e-commerce companies, the main goal of different compensation strategies is to increase retailers' platform order volume. The total platform order volume shows that the S strategy is most effective in increasing platform order volume under retailer loss aversion, and its retailer's platform order percentage is also higher than other strategies. This means that the implementation of the S-strategy can deepen the partnership, improve the quality of the empowered retailer's products and thus reduce the loss of the platform's brand value, and effectively reduce conflicts and maintain the relationship between the two partners.

4.2 Performance Analysis of S Strategy

Analyze the performance of S strategy from ρ , k_t and η_s .

From Figures 2 and 3, we can see the effect of ρ , η_s and k_t on the profit function of supply chain members under S strategy. The proportion ρ of H-type retailers has a significant impact on the profits of L-type retailers and platform-based e-commerce firms. When the ρ is too low in the platform-type e-commerce, empowering retailers' product quality can not be guaranteed, and the brand value generated loss. However, through the regulation of the brand cooperation margin and risk-sharing factor, a high-profit level can still be guaranteed. When $\rho \in \{0.28, 0.89\}$, the profit level of L-type retailers decreases, and S-strategy will have a boosting effect on L-type retailers to transform them into high-margin H-type retailers. And k_t is also a key factor influencing ρ .It can be seen from the figure that the promotion of the S strategy is more stable when k_t is higher. In addition, in a certain interval due to the S strategy under the increase in k_t as well as η_s led to higher costs platform-based e-commerce companies have decreased profits. However, the loss of brand value is reduced and the empowerment cooperation is more stable.

Figure 2 examines the S strategy when it has the greatest effect on L-type retailer improvement, i.e., $\rho = 0.8$ .As the level of brand empowerment increases, the change in retailer profits is not significant. However, when k_t is low, too high η_s increases the profit of L-type retailers and makes them more profitable than H-type retailers, which is counterproductive to the improvement effect of the retailer category. In addition, at the same level of brand empowerment, the profit gap between the two retailers will increase with the improvement of k_t .L-type retailers will transform to H-type retailers, thus optimizing the structure of empowered retailers and better-realizing value co-creation.

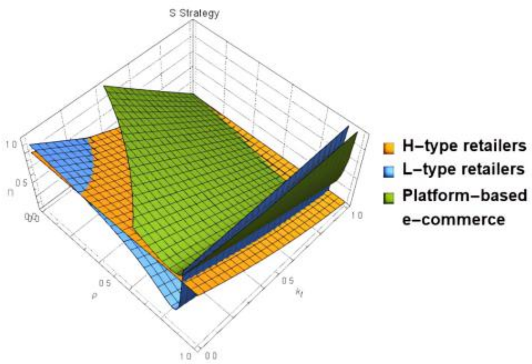

Figure 2. ρ and k_t Impact on Profit

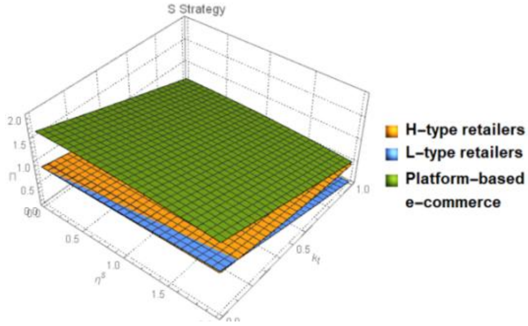

Figure 3. η_s and k_t Impact on Profit

4.3 Perturbation Analysis of Retailer Risk Aversion

(1) Analysis of the influence of retailer profits

The impact of k_t on the profitability of both retailers under different strategies is shown figuratively in Figure 4 and Figure 5. First, the figure shows that as k_t increases, the profit of H and L retailers decreases in a somewhat linear fashion for all three strategies. It shows that the risk-averse behavior of retailers in the context of stochastic market demand can have a negative impact in platform-enabled collaborations. Retailer profits are affected by risk aversion factors to different degrees under different empowerment strategies. The profit of H and L retailers take the highest S strategy at k_t >0.08 and k_t >0.2, separately. Retailers' profits under E strategy have a significant downward trend as their risk aversion increases. On the contrary, the increased risk aversion of retailers under S strategy is very effective in maintaining the profit level of retailers and minimizing the negative impact of risk aversion factors. Considering the increased uncertainty and riskiness of market demand under the post-epidemic scenario, retailers are generally at a higher value of risk aversion and are in a conservative decision-making state in cooperation decisions. The S strategy in the context of high-risk aversion becomes the optimal choice for both types of retailers.

As analysed in Figure 6, Platform-based e-merchants have the advantage of being the dominant player in the supply chain in terms of decision-making game. The degree of risk aversion of retailers in the three cooperative strategy formulations is an important influence on their profits. The model shows that at k_t > 0.18, the profit under the S strategy is the highest of the three strategies.

But its profit decreases with the increase of k_t .In the consideration of the stability of platform-enabled cooperation, the cooperation reached when the retailer's risk aversion is higher under the S strategy is more conducive to the full utilization of brand value.

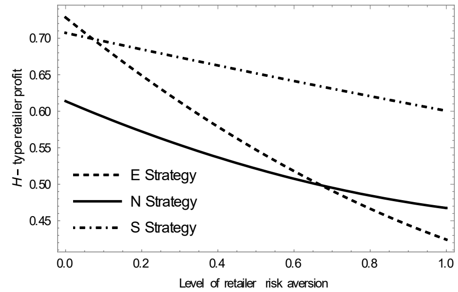

Figure 4. Impact on Profits of H Retailers

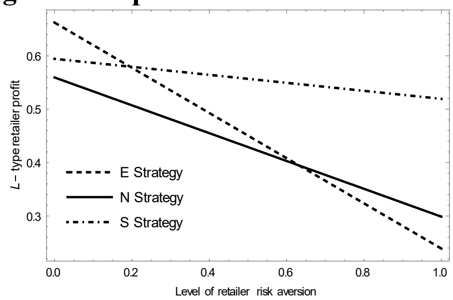

Figure 5. Impact on Profits of L Retailer

(2) Analysis of the influence of platform-based e-commerce profits

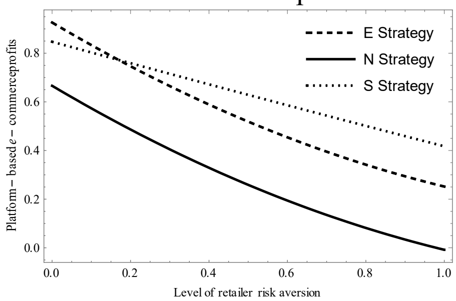

Figure 6. k_t Impact on the Profits of Platform-based E-Commerce Companies

4.4 Perturbation Analysis of Product Substitution

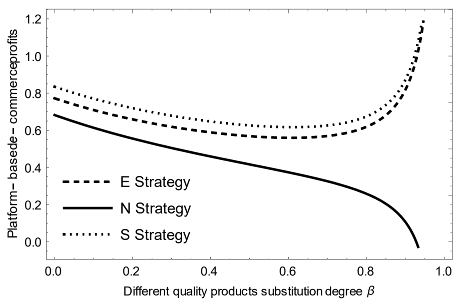

Figure 7. Impact of β Impact on the Expected Utility of Platform-based E-Commerce Firms

Figure 7 reflects the change curve of profit of platform-based e-commerce firms affected by the degree of quality-differentiated product substitution β under different strategies. The profits of platform-based e-commerce companies under the no-risk-sharing policy can be greatly impacted by low-quality products. The reason for this is the high proportion of low-quality products from other channels among the products purchased by retailers under the N strategy. This will compress the profit margin of high-quality products, increase the loss of brand value of platform-based e-commerce enterprises, and cause the intensification of vertical channel conflict. Compared with the N strategy, the E and S strategies are very effective in enhancing the profits of platform-based e-commerce companies. When β increases, it is difficult to generate equal-utility value difference with similar products due to brand empowerment. The optimal level of brand empowerment for platform-based e-commerce will then decrease. Under the E and S strategies, platform-based e-commerce companies coordinate the ordering ratio of retailers by increasing the risk-sharing factor, thus reducing vertical channel conflicts. Retailers cooperating with platform-based e-commerce companies can maintain a high level of profitability by having high or low product substitution in their product selection.

5. Conclusion

This paper analyzes the evolution of the game relationship between platform-based e-merchants and retailers based on the premise of limited rationality of decision makers. By adding elements of risk aversion, platform empowerment level, and market uncertainty, the behavioral tendencies and evolutionary laws of both sides of the game are explained from the perspective of risk perception. It bridges the gap in the existing dual-channel conflict supply chain research on the competitive relationship between platform e-commerce-dominated supply chains and other channel suppliers. It improves the deviation of the evolutionary game and expected utility theory in explaining the behavior of the retailer empowerment cooperation game. The influence of core parameters on system evolution is further explored through simulation. The deep-seated reasons for the opportunistic behavior of parties in the supply chain are dissected. A comparative analysis of the equilibrium solutions of different decision alternatives leads to the following conclusions.

S strategy by implementing differential empowerment contracts for different types of retailers. Increase the profit gap between H-type retailers and L-type retailers, which makes the proportion of order quantity of platform e-commerce companies among retailers increase. Reduces the loss of goodwill caused by low-quality products in brand empowerment.2) The platform brand empowerment adopts the act of introducing risk-sharing coefficients for risk-sharing in the empowerment contract.3) Risk-averse retailers do not need to provide a risk-sharing policy when the risk-averse level is very low. Due to the uncertainty of market demand, the risk-sharing policy adopted by platform-based e-commerce companies can effectively improve retailers' profits and the platform's profits. Retailers maintain a low level of risk aversion in brand-empowered cooperation in favor of supply chain members' profit enhancement. The findings of the study can provide theoretical suggestions for the formulation of empowerment contracts and related decisions in the platform brand empowerment supply chain under the random market demand.

This paper investigates the impact of platform-based e-commerce empowerment contracts on the profits and strategies of closed-loop supply chain members composed of retailers under three strategies of stochastic market demand. However, the loss of goodwill and retailer penalty mechanisms induced by quality differences are not addressed. Therefore, considering multiple manufacturers' and retailers' competition scenarios and information asymmetry will be the next research direction.

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