Available Online: 29 June 2026 DOI: 10.54254/2977-5701/2026.34851

Reliability risk-averse decisions in collaborative e-commerce logistics: a game-theoretic analysis of platform heterogeneity

Xiaorui Rong

School of Economics and Management, Beijing University of Posts and Telecommunications, Beijing, China

455114943@qq.com

Abstract. E-commerce competition is shifting toward backend order fulfillment, and logistics capability has become a core driver of platform differentiation. Targeting the practical dilemma that self-built logistics incurs high costs in remote areas while Third-Party Logistics (TPL) boasts extensive last-mile coverage, this paper investigates two dominant modes of collaborative logistics: self-built logistics led mode and TPL led mode. E-commerce platforms are classified into resale platforms, marketplace platforms and hybrid platforms. By endogenizing users' perceived value of logistics services, this paper constructs game models and further introduces systemic risks to analyze the impacts of reliability losses on platform profits and mode selection. The results indicate that resale platforms prefer the self-built logistics led mode when users are highly sensitive to service quality; marketplace platforms tend to adopt the TPL led mode due to the lack of pricing power; hybrid platforms need to strike a balance between in-house service quality and third-party costs, and their optimal mode depends on the intensity of channel competition. When service sensitivity exceeds a certain threshold, the self-built logistics led mode generates higher profits. After incorporating systemic risks, a higher degree of aversion to reliability losses makes the self-built logistics led mode relatively superior on account of its stronger controllability. This research provides decision-making references for different types of e-commerce platforms to optimize logistics resource allocation.

Keywords: platform type, collaborative distribution, optimization model, logistics risk, mode optimization

1. Introduction

China's online retail market ranks first across the globe in scale. In 2024, national online retail sales in China reached 15.52 trillion RMB, and online retail sales of physical goods accounted for 26.8% of the total retail sales of consumer goods. Against the backdrop that annual express delivery volume has continuously exceeded one billion parcels, the focus of competition among e-commerce platforms has shifted from front-end marketing to backend logistics fulfillment capabilities. Logistics distribution not only controls operational costs but also enhances user stickiness by improving service quality, thus evolving into a key source of differentiated competition for platforms.

Nevertheless, the geographic coverage of the e-commerce market is severely unbalanced. Single logistics modes face prominent limitations in sinking markets and remote areas with scattered orders. For resale platforms, self-built logistics suffers from high marginal costs and difficulty in achieving economies of scale in remote regions, making it necessary to rely on TPL to realize last-mile coverage. Platforms represented by JD.com deliver superior user experience via self-built logistics, yet they require heavy asset investment and operate inefficiently in regions with sparse orders. Although TPL features wide coverage and low costs, it has deficiencies in delivery speed, service quality and strategic collaboration. The contradiction between "high quality with high costs and low prices with insufficient service guarantee" has driven platforms to explore the collaborative logistics mode of "line-haul transportation plus terminal home delivery", aiming to strike an optimal balance between operational efficiency and costs.

Current domestic and international studies mainly focus on the development of self-built logistics, operational mode innovation [1] and supply chain optimization [2]. However, most studies regard self-built logistics and TPL as competing entities, with insufficient attention paid to their collaborative operation [3, 4]. A small number of researches on logistics collaboration are limited to phenomenon description or qualitative analysis, lacking game modeling and quantitative comparison on the allocation of leading power in collaborative distribution. Early literature mostly centers on the binary choice between self-built logistics and TPL. Zhang et al. [5] constructed a supply chain system consisting of manufacturers, retailers and e-commerce platforms to explore the impacts of logistics strategies and sales models. Zhang Jianxiong et al. [6] took the power structure of suppliers and logistics providers as well as brand differences into consideration, and found that suppliers should select self-operated logistics, hybrid logistics and third-party logistics in sequence when the brand gap among logistics providers is large, moderate and small respectively.

The above studies lay a foundation for understanding logistics mode selection. However, most existing literature treats self-built logistics and TPL as mutually substitutable competitors. Even researches involving collaboration only stay at the level of phenomenon description or qualitative analysis, without conducting game modeling and quantitative comparison on leading power allocation. Moreover, mainstream models generally assume e-commerce platforms as homogeneous entities and ignore the essential differences among resale platforms, marketplace platforms and hybrid platforms in terms of pricing power, commodity ownership and revenue structure. Such platform heterogeneity has not been incorporated into existing analytical frameworks.

With the development of industrial practices, the trend that self-built logistics and TPL shift from competition to collaboration has gradually attracted scholars' attention. Based on a two-stage game model, Zhao Xu et al. [7] verified that establishing a vertical distribution alliance between platforms and TPL can reduce comprehensive costs by approximately 12% compared with pure self-operation. Capacity pool sharing and risk sharing can be realized via unified Key Performance Indicators (KPI) and joint investment in sorting centers. Targeting the "last-mile" problem of rural e-commerce, Xu Ling et al. established a mixed-integer programming model for collaborative distribution using unmanned aerial vehicles and vehicles. Tang et al. [8] constructed an optimization model for logistics self-operation and outsourcing against the background of cloud manufacturing. These studies have made valuable explorations on collaborative distribution, but most of them assume homogeneous platforms and fail to consider the essential differences among platforms with different business models in pricing power and commodity ownership. Therefore, they cannot answer the strategic question of "which type of platforms is more suitable for adopting the self-built logistics led mode or the TPL led mode".

In recent years, scholars have begun to explore the intersection of platform heterogeneity and users' perceived value of logistics services. Yu Yugang et al. [9] studied the impacts of retailers sharing self-built logistics with third-party sellers, and found that logistics sharing always benefits third-party sellers, and a win-win situation for three parties can be achieved under specific conditions. It has been proven that consumers' perceived value of logistics services is a critical factor affecting users' repurchase intention, which is jointly determined by delivery time and price. Even so, in most existing game models, consumers' perceived value is simplified as a linear function of price, and the heterogeneous sensitivity of consumers to logistics service quality is not endogenized, leading to deviations between model conclusions and management practices.

Collaborative logistics distribution faces various systemic risks in actual operation, such as demand fluctuation, transportation delay and failed terminal delivery. Such uncertainties not only affect expected profits but may also change the preference of both parties for collaborative modes. Xu Xiuzhen et al. [10] modeled the distribution network as a multi-state flow network and proposed a reliability evaluation method based on minimal capacity vectors. Liu Da et al. [11] discussed the cost allocation of collaborative distribution considering differentiated customer values under uncertain demand, and adopted robust optimization to characterize demand uncertainty. A common feature of the above studies is that logistics reliability is regarded as an engineering technical indicator, focusing on operational issues such as network structure, route optimization and warehouse management. These studies fail to endogenize logistics reliability into platforms' profit functions and decision models. More importantly, few existing studies investigate how platform heterogeneity affects platforms' response strategies to logistics risks, nor do they incorporate reliability losses as decision variables into game analysis within the framework of collaborative mode selection.

This paper systematically integrates platform heterogeneity into the game analysis framework of collaborative distribution, clearly defines three types of platforms, introduces the reliability loss coefficient λ into the research on collaborative distribution, and constructs corresponding game models to reveal the internal logic of different types of platforms in selecting collaborative modes.

2. Problem description and relevant definitions

In the field of e-commerce logistics, self-built logistics and TPL have respective advantages and disadvantages. Self-built logistics delivers high service quality but requires large-scale heavy asset investment, and it is difficult to achieve economies of scale in remote areas. TPL features extensive terminal network coverage and low marginal costs, yet its service quality is poorly controllable. Accordingly, the industry has developed the collaborative distribution mode of "platform self-built line-haul transportation plus TPL terminal home delivery". Nevertheless, the attribution of leading power in collaborative distribution directly affects platforms' profit levels and service quality, and such selection is closely related to the business model of e-commerce platforms. In addition, logistics services are inherently uncertain, including terminal delivery delays and demand fluctuations. Platforms' aversion to such risks will also alter their preference for different collaborative modes. This paper aims to address the above issues by constructing game models, comparing the equilibrium results of two collaborative modes across three types of platforms, and revealing the influencing mechanism of platform types, consumers' perceived value and risk attitudes on optimal logistics strategies.

Based on commodity ownership and transaction matching methods in business models, this paper divides e-commerce platforms into three categories as follows:

Resale Platform: The platform purchases commodities directly from suppliers, acquires commodity ownership, and then resells commodities to consumers through its own channels.

Marketplace Platform: The platform does not own commodity ownership and only provides an online trading venue for third-party sellers and consumers.

Hybrid Platform: The platform operates both resale business and intermediary business. The two types of channels coexist on one platform and present both competition and collaboration.

This paper studies the collaboration between self-built logistics and third-party logistics.

Self-built Logistics: A logistics system independently invested, constructed and operated by e-commerce platforms, including warehouses, line-haul fleets and delivery teams.

Third-Party Logistics (TPL): An independent logistics service provider outside e-commerce platforms that provides warehousing, transportation, terminal delivery and other services for multiple e-commerce merchants.

In collaborative distribution, two modes are classified according to the leading party:

Mode 1 (Self-built Logistics Led Mode): The platform's self-built logistics undertakes line-haul transportation and entrusts TPL with terminal home delivery. The platform first determines the final logistics service price and then sets the outsourcing price.

Mode 2 (TPL Led Mode): TPL is responsible for terminal delivery and sets the outsourcing price for entrusted orders, and the platform determines the logistics service price for end consumers based on the outsourcing price.

The symbols and corresponding definitions used in this paper are presented in Table 1.

Table 1. Symbol definitions

Symbol	Definition	Unit
a	Total potential market demand	Order
b	Sensitivity coefficient of demand to logistics service unit price	/
k	Consumers' perceived value of logistics services	/
p	Unit price of logistics service	RMB per order
R	Overall reliability of logistics services	/
R_P	Logistics service reliability under self-built logistics led mode	/
R_T	Logistics service reliability under TPL led mode	/
z_P	Influence factor of logistics perceived value under self-built logistics led mode	/
z_T	Influence factor of logistics perceived value under TPL led mode	/
$C_P(s_P)$	Logistics service cost under self-built logistics led mode	RMB
$C_T(s_T)$	Logistics service cost under TPL led mode	RMB
π_{ep}	Profit under self-built logistics led mode	RMB
π_{TPL}	Profit under TPL led mode	RMB
r	Commission fee	RMB per order
f	Unit logistics fee charged by the platform from sellers	RMB per order
γ	Cross-price sensitivity coefficient	/
ω	Outsourcing price accepted by logistics service providers	RMB per order

λ	Reliability loss aversion coefficient	/

3. Model assumptions, formulation and solution

3.1 Model assumptions

This paper focuses on the e-commerce logistics scenario of single-category and homogeneous commodities (such as standardized electronic products and daily necessities). Assume the total market capacity is a, and all consumers face a uniform unit price of logistics service p without differentiated pricing. Specific model assumptions are as follows:

Assumption 1: Demand Function. Referring to classical supply chain game literature [7, 13], this paper adopts a linear demand function $D\left(p,s\right)=a-bp+kR$ affected by the unit price of logistics service p and overall logistics service reliability R, to reflect consumers' sensitivity to price and service reliability. Total consumer demand is positively correlated with total market demand a and service reliability R, and negatively correlated with the unit price of logistics service p. Among the parameters, b represents the sensitivity coefficient of demand to the unit price of logistics service, and k denotes the logistics perceived value coefficient (consumers' comprehensive subjective evaluation of platform logistics service quality when placing orders, which is jointly determined by delivery speed, on-time rate, parcel intact rate, timeliness of information update and other factors. A higher value of k means that the platform can obtain greater demand growth by improving service quality). It is specified that $a,b>0$.

Assumption 2: Cost Function. The cost of logistics service is a quadratic function of service level, reflecting the law of increasing marginal cost. According to previous studies on the functional relationship between logistics technology investment and performance output, the input cost is set as $C=\frac{1}{2}zR^2$, where z is the influence factor of logistics perceived value. The cost functions of the platform and TPL are presented as follows:

Cost function of the platform (Formula (1)):

$$C_P\left(R_P\right)=\frac{1}{2}z_P{R_P}^2 \tag{1}$$

Cost function of TPL (Formula (2)):

$$C_T\left(R_T\right)=\frac{1}{2}z_T{R_T}^2 \tag{2}$$

where z_P and z_T are the influence factors of logistics perceived value under the self-built logistics led mode and TPL led mode respectively; R_p and R_T represent the service reliability under the self-built logistics led mode and TPL led mode respectively.

3.2 Game model solution for resale platforms

For resale platforms, the platform itself acts as a seller, directly selling commodities to consumers and determining the pricing of logistics services. The profit composition of game participants varies with the leading party of collaborative distribution. Under either mode, the platform's revenue is derived from the product of the logistics service unit price p paid by consumers and total demand D. Meanwhile, the platform needs to pay outsourcing fees to TPL (under the self-built logistics led mode) or bear the costs of self-built logistics (under the TPL led mode). TPL's revenue comes from the outsourcing fees paid by the platform minus its own operational costs. The total supply chain profit is the sum of the two parties' profits. In a unified form regardless of leading modes, the profit functions of each participant are written as follows:

Platform profit (Formula (3)):

$$\pi_{ep} = (p_r - \omega)D - C_P(R_P) \tag{3}$$

TPL profit (Formula (4)):

$$\pi_{TPL} = \omega D - C_T(R_T) \tag{4}$$

Total supply chain profit (Formula (5)):

$$\pi_{\text{Reseller}} = \pi_{ep} + \pi_{TPL} = p_r D - C_P(R_P) - C_T(R_T) \tag{5}$$

where π_{ep} and π_{TPL} refer to the profits of the platform and TPL respectively; $C_P(R_P)$ and $C_T(R_T)$ represent the costs under the self-built logistics led mode and TPL led mode respectively; D is total consumer demand.

3.2.1 Self-built logistics led mode

Under the self-built logistics led mode, the platform occupies a dominant position in the collaborative distribution system by virtue of its self-built line-haul network and brand advantages, acting as the leader in the Stackelberg game. As the provider of terminal home delivery services, TPL can only passively accept the cooperation terms set by the platform and thus serves as the follower. This power structure reflects the irreplaceable role of e-commerce platforms with self-operated logistics capabilities in line-haul transportation and the subordinate position of TPL in terminal delivery in specific regions in practice.

In Mode 1, the platform is the leader of the Stackelberg game and TPL is the follower. The decision sequence is as follows:

Stage 1: The platform simultaneously determines the service reliability of self-built logistics R_P and the internal transfer price ω.

Stage 2: After observing R_P and ω, TPL determines its own service reliability R_T .

Stage 3: After observing R_T, the platform sets the final retail price p_r.

The final results are obtained as follows: ${R_T}^{*(1)} = \frac{kw_2\omega}{2z_T}$, retail price ${p_r}^{*(1)} = \omega + \frac{z_P M}{2bz_P - k^2{w_1}^2}$, platform profit ${\pi_{ep}}^{*(1)} = \frac{z_P M^2}{2(2bz_P - k^2{w_1}^2)}$, TPL profit ${\pi_{TPL}}^{*(1)} = \frac{\omega b z_P M}{2bz_P - k^2{w_1}^2} - \frac{\omega^2{w_2}^2k^2}{8z_T}$, and total supply chain profit $\pi^* = {\pi_{ep}}^* + {\pi_{TPL}}^*$.

3.2.2 TPL led mode

Under Mode 1, the platform holds the leading position relying on its line-haul capacity of self-built logistics. However, in actual e-commerce logistics scenarios, especially in remote areas or regions with low order density, TPL possesses stronger bargaining power by virtue of its extensive terminal network coverage and economies of scale. In this case, TPL becomes the leader in collaborative distribution, while the platform turns into the follower. This section analyzes the equilibrium under such reversed power structure, and the decision sequence is as follows:

Stage 1: TPL determines its service reliability R_T and the internal transfer price ω charged to the platform.

Stage 2: After observing ω and R_T, the platform determines the service reliability of its self-built logistics R_P.

Stage 3: After observing R_P, the platform sets the retail price p_r.

The backward induction method is adopted to solve for the subgame perfect Nash equilibrium, which starts from the last stage and solves recursively forward, similar to Mode 1.

Substitute the solved ω and R_T into relevant expressions to obtain all equilibrium variables: ${R_T}^{*(2)} = \frac{z_P k a w_2}{2z_T\left(2bz_P-k^2{w_1}^2\right)-z_P k^2{w_2}^2}$, $\omega^{*(2)} = \frac{a+kw_2R_T}{2b}$, ${R_P}^{*(2)} = \frac{akw_1}{2\left(2bz_P-k^2{w_1}^2\right)}$, ${\pi_{ep}}^{*(2)} = \frac{a^2z_Pz_T}{8\left(2bz_P-k^2{w_1}^2\right)z_T\text{-}4z_Pk^2{w_2}^2}$, ${\pi_{TPL}}^{*(2)} = \frac{a^2z_Pz_T\left[\left(2bz_P-k^2{w_1}^2\right)z_T-z_Pk^2{w_2}^2\right]}{\left[\left(4bz_P-2k^2{w_1}^2\right)z_T-z_Pk^2{w_2}^2\right]^2}$.

3.3 Game model solution for marketplace platforms

This section investigates the two collaborative modes (self-built logistics led mode and TPL led mode) targeting marketplace platforms. The biggest difference between marketplace platforms and resale platforms lies in that marketplace platforms do not directly set the final commodity price, but indirectly affect the pricing behavior of sellers by setting commission fee r and unit logistics fee f.

The marketplace platform acts as an intermediary providing services for third-party sellers. Game participants include the platform, sellers and TPL. Sellers set the retail price p_m. The platform charges commission fee r and logistics fee f from sellers, so the platform's unit revenue is $r+f$. The platform pays the collaboration price ω to TPL.

Seller profit: $\pi_{er} = (p_m - r - f)D$

Platform profit: $\pi_{ep} = (r + f - \omega)D - C_P(R_P)$

TPL profit: $\pi_{TPL} = \omega D - C_T(R_T)$

Total supply chain profit: $\pi_{Market} = \pi_{er} +_{ep} + \pi_{TPL} = p_m D(p_m, R_P + R_T) - C_P(R_P) - C_T(R_T)$

Under either Mode 1 or Mode 2, in the final stage of the game, sellers are faced with the known demand function $Q = a - bp_m + kR$, fixed unit cost $F = r + f$ and logistics reliability R. Sellers select p_m to maximize their own profit (Formula (6)):

$$\pi_{er} = (p_m - r - f)\left[a - bp_m + k\left(w_1R_P + w_2R_T\right)\right] \tag{6}$$

Calculate the first-order partial derivative with respect to p_m (Formula (7)):

$$\frac{\partial \pi_{er}}{\partial p_m} = a - 2bp_m + k\left(w_1R_P + w_2R_T\right) + b\left(r + f\right) \tag{7}$$

Set the first-order derivative equal to zero and solve the equation (Formula (8)):

$$p_m = \frac{a+k(w_1R_P+w_2R_T)+b(r+f)}{2b} \tag{8}$$

It can be concluded that sellers will raise commodity prices to pass on costs when the platform increases commissions or logistics fees.

Substitute p_m into the demand function to obtain total demand Q (Formula (9)):

$$Q = \frac{a+k(w_1R_P+w_2R_T)-b(r+f)}{2} \tag{9}$$

3.3.1 Self-built logistics led mode

Under Mode 1, the platform acts as the Stackelberg leader by virtue of its line-haul capacity of self-built logistics. The decision sequence is as follows:

(1) The platform determines the service reliability of self-built logistics R_P and unit revenue F.

(2) After observing R_P and F, TPL determines its service reliability R_T.

(3) Sellers set the retail price p_m based on F and R_T.

The backward induction method is adopted for solution.

The final equilibrium results are derived as follows: ${R_T}^{*(3)} = \frac{\omega k w_2}{2z_T}$, ${R_P}^{*(3)} = \frac{k w_1 (M - b\omega)}{4bz_P - k^2 {w_1}^2}$, where $M = a + \omega\left(\frac{k^2 {w_2}^2}{2z_T} - b\right)$, ${\pi_{ep}}^{*(3)} = \frac{z_P\left[a+\omega\left(\frac{k^2{w_2}^2}{2z_T}-2b\right)\right]^2}{2\left(4bz_P - k^2{w_1}^2\right)}$, ${\pi_{TPL}}^{*(3)} = \frac{\omega\left(2bz_P - k^2{w_1}^2\right)\left[a+\omega\left(\frac{k^2{w_2}^2}{2z_T}-2b\right)\right]}{2\left(4bz_P - k^2{w_1}^2\right)} - \frac{\omega^2 k^2 {w_2}^2}{8z_T}$.

3.3.2 TPL led mode

The decision sequence is as follows:

(1) TPL determines its service reliability R_T and internal transfer price ω.

(2) After observing R_T and ω, the platform determines the service reliability of self-built logistics R_P and unit revenue F.

(3) Sellers set the retail price p_m.

In the third stage, sellers' pricing is determined by Formula (8) and Formula (9).

In the second stage, given R_T and ω , the platform selects $R_P \geq 0$ and $r + f \geq 0$ to maximize its own profit, where $Q = \frac{1}{2}\left[a + k\left(w_1 R_P + w_2 R_T\right) - b\left(r + f\right)\right]$ and $R = w_1 R_P + w_2 R_T$.

The platform's profit function is shown in Formula (10):

$$\pi_{ep} = \frac{1}{2}(r + f - \omega)\left[a + k w_1 R_P + k w_2 R_T - b(r + f)\right] - \frac{1}{2} z_P {R_P}^2 \tag{10}$$

The platform maximizes the above function by selecting R_P and F, and calculates partial derivatives respectively (Formula (11)):

$$\frac{\partial \pi_{ep}}{\partial R_P} = \frac{K w_1}{2}(r + f - \omega) - z_P R_P = 0 \tag{11}$$

Solve the equation to obtain Formula (12) and Formula (13):

$$R_P = \frac{K w_1}{2z_P}(r + f - \omega) \tag{12}$$

$$\frac{\partial \pi_{ep}}{\partial F} = Q - \frac{b}{2}(F - \omega) = 0 \tag{13}$$

It is solved that $F = \frac{2Q}{b} + \omega$. Substitute Q into the formula, and finally derive: $F = \frac{a + k w_1 R_T}{2b} \cdot \frac{1}{1 - \frac{k^2 {w_1}^2}{4bz_P}} + \omega$

In the first stage: optimal decision of TPL.

Equilibrium solutions can be calculated based on Formula (12) and Formula (13), and then the platform profit is obtained: ${s_T}^{*(4)} = \frac{z_P k a w_2}{2\left(2bz_T z_P - k^2{w_1}^2 z_T - k^2{w_2}^2 z_P\right)}$, ${\omega}^{*(4)} = \frac{a\left(4bz_P - k^2{w_1}^2\right)z_T}{2b\left(2bz_T z_P - k^2{w_1}^2 z_T - k^2{w_2}^2 z_P\right)}$, ${s_P}^{*(4)} = \frac{akw_1 z_T}{2\left(2bz_T z_P - k^2{w_1}^2 z_T - k^2{w_2}^2 z_P\right)}$, ${Q}^{*(4)} = \frac{abz_P z_T}{2\triangle_r z_T - z_P k^2}$, $R = \frac{a\left(4bz_P - k^2{w_1}^2\right)z_T}{2b\left(2bz_T z_P - k^2{w_1}^2 z_T - k^2{w_2}^2 z_P\right)}$, ${\pi_{ep}}^{*(4)} = \frac{a^2k^2{w_1}^2 z_P {z_T}^2}{8\left(2bz_T z_P k^2{w_1}^2 z_T k^2{w_2}^2 z_P\right)^2}$, ${\pi_{TPL}}^{*(4)} = \frac{a^2 z_P z_T\left(4bz_P - k^2{w_1}^2\right)}{8\left(2bz_T z_P k^2{w_1}^2 z_T k^2{w_2}^2 z_P\right)^2}$.

3.4 Game model solution for hybrid platforms

A hybrid e-commerce platform operates both self-run business and intermediary business for third-party sellers, so the platform acts as both a seller and an intermediary. The platform owns self-built logistics capabilities and can entrust TPL to complete terminal delivery. Consumers' demand for self-operated commodities and commodities sold by third-party sellers is jointly affected by price and logistics service level, and the two types of commodities are substitutive. Thus, the cross-price sensitivity coefficient is introduced.

3.4.1 Demand function

The demand functions for the self-operated channel and the third-party seller channel are set as Formula (14) and Formula (15) respectively:

$$D_r = a_r - b_r p_r + \gamma p_m + kR \tag{14}$$

$$D_m = a_m - b_m p_m + \gamma p_r + kR \tag{15}$$

where p_r denotes the retail price of self-operated commodities, p_m denotes the retail price of commodities sold by third-party sellers, a_r and a_m represent the potential market demand of each channel, b_r and b_m are own-price sensitivity coefficients, and γ is the cross-price sensitivity coefficient reflecting the substitution degree between channels, satisfying $0 < \gamma < \min\left(b_r, b_m\right)$.

3.4.2 Profit function

Profit of third-party sellers (Formula (16)):

$$\pi_{er} = (p_m - r - f)D_m \tag{16}$$

The platform's profit is derived from sales revenue of self-operated commodities, commissions and logistics fees. Meanwhile, the platform needs to pay outsourcing fees to TPL and bear the costs of self-built logistics (Formula (17)):

$$\pi_{ep} = p_r D_r + (r + f)D_m - \omega\left(D_r + D_m\right) - C_P\left(R_P\right) \tag{17}$$

TPL profit (Formula (18)):

$$\pi_{TPL} = \omega\left(D_r + D_m\right) - C_T\left(R_T\right) \tag{18}$$

Total supply chain profit (Formula (19)):

$$\pi_{Hybrid} = \pi_{ep} + \pi_{TPL} + \pi_{er} = p_r D_r + p_m D_m - C_P\left(R_P\right) - C_T\left(R_T\right) \tag{19}$$

3.4.3 Simplified assumptions

To obtain analytical solutions conveniently, this paper assumes symmetric market bases for the two channels, i.e., $a_r = a_m = a$ and $b_r = b_m = b$. This assumption is widely adopted in similar studies [12, 13] and will not affect the qualitative analysis of core conclusions. The cross-price sensitivity coefficient γ remains general.

3.4.4 Price competition equilibrium in the third stage

In the final stage of the game, the logistics service level $R = w_1 R_P + w_2 R_T$ is given. The platform's decision variables ω and f , as well as R_P, R_T, ω and f , are all determined, and r is an exogenous constant. The platform and sellers simultaneously set retail prices to maximize their respective profits.

Based on the first-order conditions $\frac{\partial \pi_{ep}}{\partial p_r} = 0$ and $\frac{\partial \pi_{er}}{\partial p_m} = 0$, we obtain Formula (20):

$$\begin{cases} a - 2bp_r + \gamma p_m + kR + b\omega + \gamma\left(r + f - \omega\right) = 0 \\ a + \gamma p_r - 2bp_m + kR + b\left(r + f\right) = 0 \end{cases} \tag{20}$$

Let $A = a + kR + (b-\gamma)\omega + \gamma\left(r + f\right)$ and $B = a + kR + b\left(r + f\right)$. The matrix form of the equation set is Formula (21):

$$\begin{pmatrix} 2b & -\gamma \\ -\gamma & 2b \end{pmatrix}\begin{pmatrix} p_r \\ p_m \end{pmatrix} = \begin{pmatrix} A \\ B \end{pmatrix} \tag{21}$$

The determinant of the coefficient matrix is $\triangle = 4b^2 - \gamma^2 > 0$, and the solutions are derived as Formula (22):

$$p_r = \frac{2bA+\gamma B}{4\mathrm{b}^2-\gamma^2}, p_m = \frac{\gamma A+2bB}{4b^2-\gamma^2} \tag{22}$$

Total demand $D = D_r + D_m$ is expressed as Formula (23):

$$D = 2a + (\gamma - b)\left(p_r + p_m\right) + 2kR \tag{23}$$

Partial derivatives of price with respect to service level are required in subsequent game analysis. Take partial derivatives of Formula (20) with respect to s , and we obtain Formula (24):

$$2b\frac{\partial p_r}{\partial R} - \gamma\frac{\partial p_m}{\partial R} = k, -\gamma\frac{\partial p_r}{\partial R} + 2b\frac{\partial p_m}{\partial R} = k \tag{24}$$

Solve the equation set to obtain Formula (25):

$$\frac{\partial p_r}{\partial R} = \frac{\partial p_m}{\partial R} = \frac{k(2b+\gamma)}{4b^2-\gamma^2} \equiv {z_P}' \tag{25}$$

Furthermore, the partial derivative of total demand with respect to s is Formula (26):

$$\frac{\partial D}{\partial R} = 2k + 2(\gamma - b){z_P}' = \frac{2bk(2b+\gamma)}{4b^2-\gamma^2} = {D_R}' \tag{26}$$

3.4.5 Self-built logistics led mode

The decision sequence is as follows:

(1) The platform determines R_P , ω and f .

(2) After observing R_P , ω and f , TPL determines its service reliability R_T .

(3) The platform and sellers simultaneously set retail prices p_r and p_m to reach Nash equilibrium.

Given R_P , ω and f , TPL's profit is $\pi_{TPL} = \omega D(R, \omega, f) - C_P(R_P)$,
where $R = w_1 R_P + w_2 R_T$ and $D(R, \omega, f)$ is determined by the equilibrium results in the third stage. As shown in Formula (27), $D_R{}'$ is a constant, so the first-order condition for TPL is Formula (27):

$$\frac{\partial \pi_{TPL}}{\partial R_T} = \omega w_2 D_R{}' - z_T R_T = 0 \tag{27}$$

Solve the equation to obtain Formula (28):

$$R_T = \frac{\omega w_2 D_R{}'}{z_T} \equiv \alpha\omega \tag{28}$$

where $\alpha = \frac{w_2 D_R{}'}{z_T} = \frac{2bw_2k(2b+\gamma)}{z_T\triangle}{}'$.

The platform anticipates TPL's reaction function (Formula (28)) and substitutes $R_T = \alpha\omega$ into the model. Thus the total service level $R = R_P + \alpha\omega$. π_{ep} becomes a quadratic function of R_P , ω and f . The first-order conditions for the platform's maximization problem are Formula (29):

$$\begin{cases} \frac{\partial \pi_{ep}}{\partial R_P} = 0 \\ \frac{\partial \pi_{ep}}{\partial \omega} = 0 \\ \frac{\partial \pi_{ep}}{\partial f} = 0 \end{cases} \tag{29}$$

The optimal solutions are derived as follows: $R_P{}^* = \frac{k\cdot f_1(a,b,\gamma,z_P,z_T,w_1,w_2,r)}{f_2(b.\gamma,z_P,z_T,w_1,w_2)}$, $\omega^* = \frac{a\cdot f_3(b,\gamma,z_P,z_T,w_1,w_2)}{f_4(b,\gamma,z_P,z_T,w_1,w_2)}$ and $f^* = \frac{a\cdot f_5(b,\gamma,z_P,z_T,w_1,w_2)}{f_6(b,\gamma,z_P,z_T,w_1,w_2)} - r$, Substitute the optimal solutions into relevant formulas to derive $R_T{}^* = \alpha\omega^*$, and further calculate $\pi_{ep}{}^{*(5)}, \pi_{TPL}{}^{*(5)}, \pi_{Hybrid}{}^{*(5)}$.

3.4.6 TPL led mode

The decision sequence is as follows:

(1) TPL determines R_T and ω .

(2) After observing R_T and ω , the platform determines R_P and f .

(3) The platform and sellers simultaneously set retail prices p_r and p_m .

Given R_T and ω , the platform selects R_P and f to maximize its own profit. The platform's first-order conditions are $\frac{\partial \pi_{ep}}{\partial R_P} = 0, \frac{\partial \pi_{ep}}{\partial f} = 0$. Solve the equations and express R_P and f as linear functions of R_T and ω, as shown in Formula (30):

$$R_P = \beta_1 R_T + \beta_2\omega + \beta_3, f = \gamma_1 R_T + \gamma_2\omega + \gamma_3 - r \tag{30}$$

The coefficients β_i, γ_i are determined by parameters a, b, γ, k, z_P, z_T .

TPL sets first-order conditions for profit maximization (Formula (31)):

$$\frac{\partial \pi_{TPL}}{\partial R_T} = 0, \frac{\partial \pi_{TPL}}{\partial \omega} = 0 \tag{31}$$

Solve the equations to obtain the optimal ${R_T}^*$ and ω^*, then substitute the results back into Formula (17) to derive f^*. Finally, retail prices and profits are calculated:

$${R_T}^{*(6)} = \frac{a \cdot g_1(b,\gamma,k,z_P,z_T,w_1,w_2)}{g_2(b.\gamma,k,z_P,z_T,w_1,w_2)}, \quad \omega^{*(6)} = \frac{a \cdot g_3(b,\gamma,k,z_P,z_T,w_1,w_2)}{g_4(b,\gamma,k,z_P,z_T,w_1,w_2)}, \quad f^{*(6)} = \frac{a \cdot g_5(b,\gamma,k,z_P,z_T,w_1,w_2)}{g_6(b,\gamma,k,z_P,z_T,w_1,w_2)} - r,$$

${\pi_{ep}}^{*(6)}, {\pi_{TPL}}^{*(6)}, {\pi_{Hybrid}}^{*(6)}$ are further derived accordingly.

4. Comparative analysis across platform types

4.1 Comparison between two modes for the same platform type

Table 2 presents the profits of the two modes for resale platforms and marketplace platforms.

Table 2. Profits of two modes for resale and marketplace platforms

	Self-built Logistics Led Mode	TPL Led Mode
Resale Platform	${\pi_{ep}}^{*(1)} = \frac{z_P M^2}{2(2bz_P - k^2{w_1}^2)}$	${\pi_{ep}}^{*(2)} = \frac{a^2 z_P z_T}{8[2bz_P - k^2{w_1}^2)z_T\text{-}4z_P k^2{w_2}^2}$
Marketplace Platform	${\pi_{ep}}^{*(3)} = \frac{z_P\left[a + \omega\left(\frac{k^2{w_2}^2}{2z_T} - 2b\right)\right]^2}{2(4bz_P - k^2{w_1}^2)}$	${\pi_{ep}}^{*(4)} = \frac{a^2k^2{w_1}^2 z_P{z_T}^2}{8(2bz_T z_P k^2{w_1}^2 z_T k^2{w_2}^2 z_P)^2}$

Proposition 1: For resale platforms, the self-built logistics led mode is superior when the weight w_1 of self-built logistics in consumers' perceived value and the logistics service sensitivity coefficient k are relatively high; the TPL led mode is preferable when the weight w_2 of TPL in consumers' perceived value and the logistics service sensitivity coefficient k are relatively low.

Proposition 2: For marketplace platforms, an increase in commission fees will amplify the relative revenue advantage of the self-built logistics led mode, and the influence degree depends on w_1 and w_2 (the weights of self-built logistics and TPL in consumers' perceived value). A larger w_1 means that a relatively low commission fee can support the adoption of the self-built logistics led mode; a larger w_2 makes the TPL led mode more likely to be the optimal strategy.

Proposition 3: For hybrid platforms, the self-built logistics led mode outperforms the TPL led mode in most parameter intervals. A higher cross-price sensitivity coefficient γ further expands the advantage of Mode 1, because self-built logistics can provide differentiated service reliability for self-operated channels and alleviate price competition. When consumers' service perception coefficient k rises, the profit of Mode 1 grows faster than that of Mode 2, and the improvement of service sensitivity strengthens the relative advantage of the self-built logistics led mode. When w_2 (the weight of TPL in consumers' perceived value) is large and terminal delivery exerts a greater impact on user experience, the relative disadvantage of Mode 2 is narrowed, but Mode 1 still maintains its superiority.

4.2 Numerical simulation and sensitivity analysis

To verify the effectiveness of the theoretical model and clarify the optimal collaborative mode for different types of platforms, this chapter conducts numerical simulation analysis based on the equilibrium solutions derived in Chapter 3, and introduces the reliability loss aversion coefficient λ. Referring to industrial data of e-commerce logistics and relevant literature [7], the benchmark parameter settings are shown in Table 3.

Table 3. Benchmark parameter settings

Parameter	a	b	k	Z_P	Z_T	r	γ	w_1	w_2	λ	f
Value	30	20	1	2	2	5	0.2	0.5	0.5	0.2	1

Sensitivity analysis is carried out on key parameters to verify the propositions and reveal the evolution rules of optimal modes. All other parameters are fixed at benchmark values, and k, r and γ are changed one by one to observe the variation of optimal modes.

Figure 1 illustrates the profit changes of resale platforms with different weights under risks. The left graph presents the scenario without risks, while the right graph incorporates risk penalties into profits to characterize uncertainties brought by increased service sensitivity.

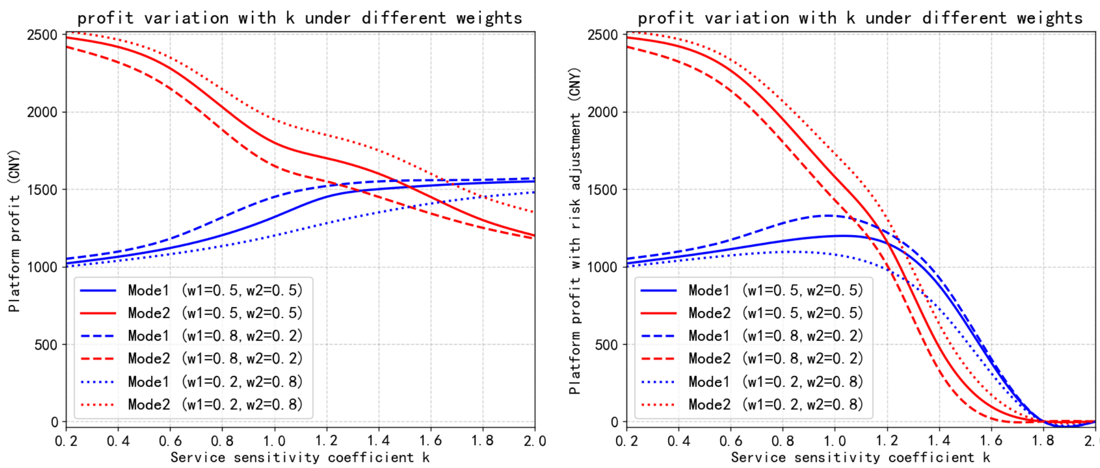

Figure 1. Profit variation of resale platforms with k under different weights

It can be observed from Figure 1 that the profit of Mode 1 rises monotonously with the increase of k, while the profit of Mode 2 declines monotonously with the increase of k. The intersection points of the two curves vary under different weight combinations. A larger w_1 means that the self-built logistics led mode exerts a greater impact, the intersection point moves leftward and the platform profit under the self-built logistics led mode is higher. A larger w_2 indicates that the TPL led mode plays a more important role, the intersection point moves rightward and the platform profit under the TPL led mode is higher. Risks push both curves downward when k takes a large value and slightly shift the intersection point leftward, which demonstrates that risk aversion strengthens the advantages of the self-built logistics led mode.

The results clearly reveal the influencing mechanism of logistics service sensitivity on the optimal collaborative mode of resale platforms: when consumers have low sensitivity to logistics service quality (small k), platforms should adopt the TPL led mode to gain higher revenue relying on TPL's cost advantages.

Figure 2 presents the profit variation of marketplace platforms with k under different weights.

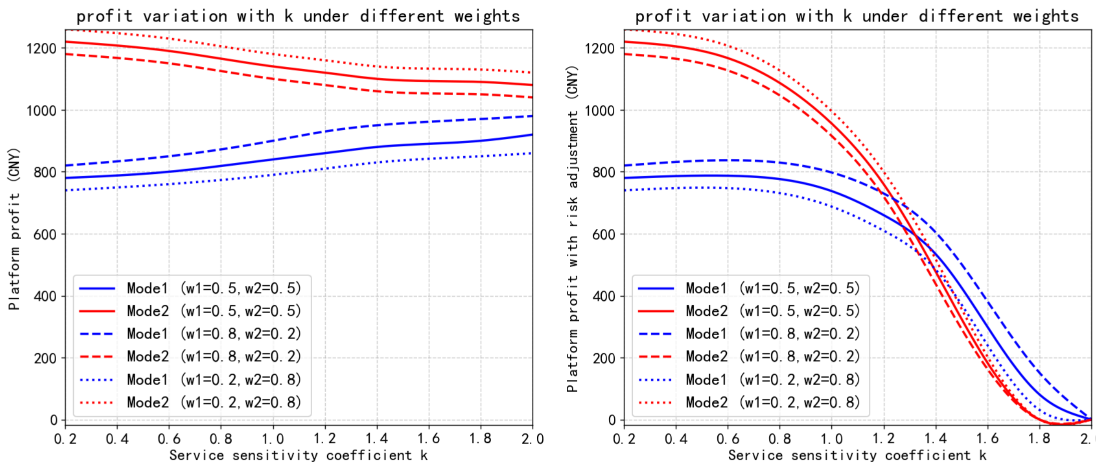

Figure 2. Profit variation of marketplace platforms with k under different weights

The profit of Mode 1 generally rises slowly with the increase of k When consumers attach greater importance to service quality, the high-quality service of self-built logistics can slightly boost market demand, yet the growth rate is limited by high costs. The profit of Mode 2 usually declines slowly with the increase of k . The insufficient service quality of TPL restrains market demand when service sensitivity rises, but TPL will moderately improve service quality, leading to a slowdown in the profit decline rate. The curve of Mode 2 always stays above the corresponding curve of Mode 1 regardless of the value of k . This indicates that for marketplace platforms, the high costs of self-built logistics cannot be passed on via commissions, while the TPL led mode delivers higher profits all the time by virtue of lower operational costs and flexible resource allocation.

A larger w_1 narrows the relative disadvantage of the self-built logistics led mode, and a larger w_2 expands the advantages of the TPL led mode. After introducing reliability loss penalties, all profit curves shift downward, and the decline range is larger in the region with high k values. The higher the service sensitivity, the greater the expected losses caused by uncertainties in the logistics system. The profit decline of Mode 2 is more significant than that of Mode 1. The terminal delivery link under the TPL led mode is more vulnerable to external disturbances such as weather, traffic and outlet management fluctuations, resulting in higher reliability losses. In contrast, self-built logistics features stronger controllability and lower risk exposure. Although overall profits decrease, Mode 2 still outperforms Mode 1, and risks do not change the core conclusion that the TPL led mode is always superior.

Figure 3 shows the profit variation of marketplace platforms with r under different weights.

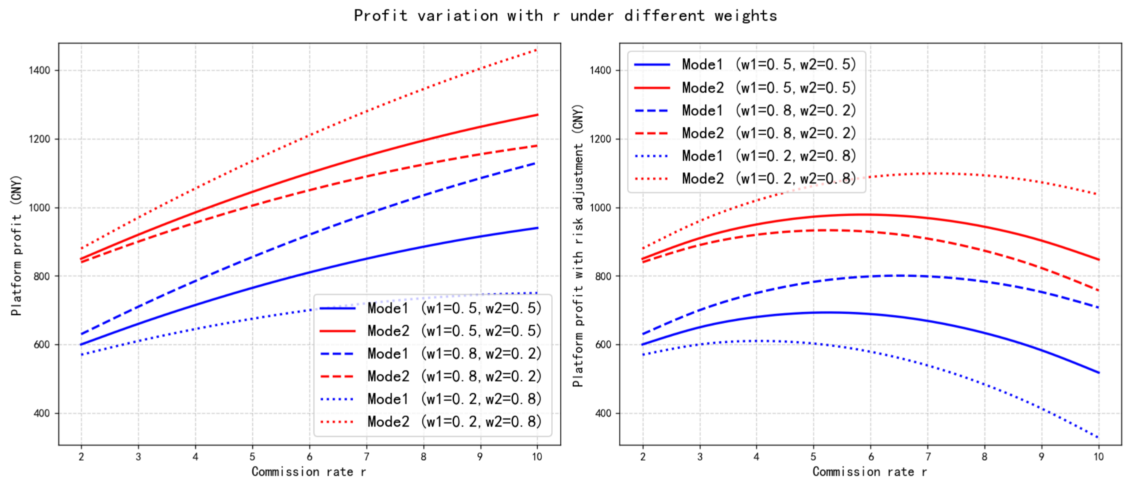

Figure 3. Profit variation of marketplace platforms with *r* under different weights

In the risk-free scenario, all profit curves rise monotonously with the increase of *r*, and the growth rate gradually slows down. As an important revenue source for platforms, higher commissions directly increase platform profits. However, excessively high commissions will dampen sellers' enthusiasm and increase demand elasticity, thus leading to diminishing marginal returns. The profit of Mode 2 is always higher than that of Mode 1. The TPL led mode has a superior cost structure, allowing platforms to retain more profits per transaction and become more sensitive to revenue growth brought by commission increases.

After introducing reliability loss penalties, all profit curves shift downward, and the decline range is larger in the region with high commission fees. Excessively high commissions may induce sellers to reduce service quality and increase risk exposure of the logistics system. The profit decline of Mode 2 is greater than that of Mode 1, which is consistent with the risk effect shown in Figure 2. Risks do not alter the conclusion that Mode 2 is always superior to Mode 1, but the profit gap between the two modes narrows in the high commission region. This means that in market environments with high risks, platforms should not over-rely on commission revenue and may appropriately consider developing self-built logistics to enhance service reliability.

Figure 4 presents the profit variation of hybrid platforms with *k* under different weights.

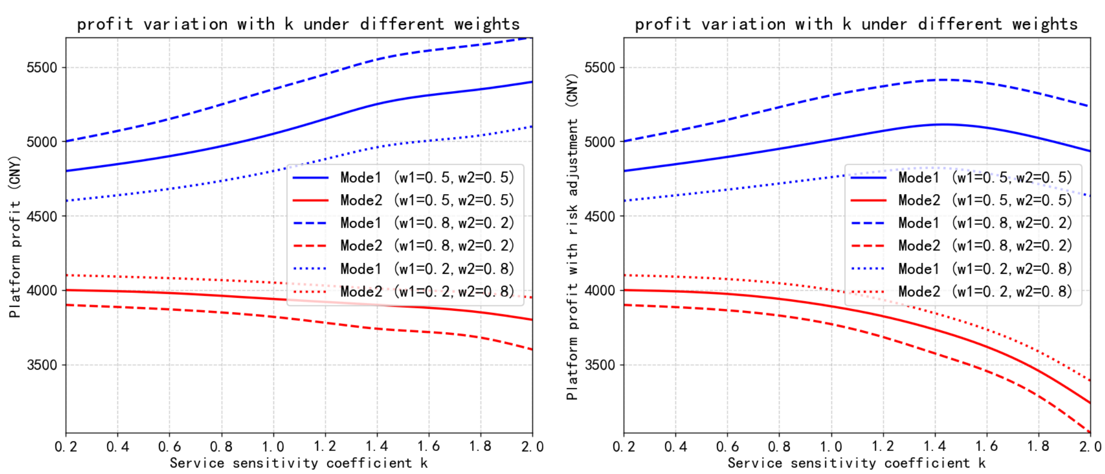

Figure 4. Profit variation of hybrid platforms with *k* under different weights

Due to channel competition, the profit of Mode 1 is always higher than that of Mode 2 for hybrid platforms, and the profit gap expands with the increase of k. This indicates that the improvement of service sensitivity further reinforces the necessity of adopting the self-built logistics led mode. After introducing risk penalties, all profit curves shift downward, and the profit decline of Mode 2 is more obvious than that of Mode 1, which further widens the profit gap between Mode 1 and Mode 2. The TPL led mode faces more uncertainties in terminal delivery and incurs higher risk costs, while self-built logistics has stronger controllability and lower risk exposure. Therefore, hybrid platforms should adhere to the self-built logistics led mode to avoid profit losses caused by systemic risks in high-risk environments.

Figure 5 illustrates the profit variation of hybrid platforms with γ under different weights.

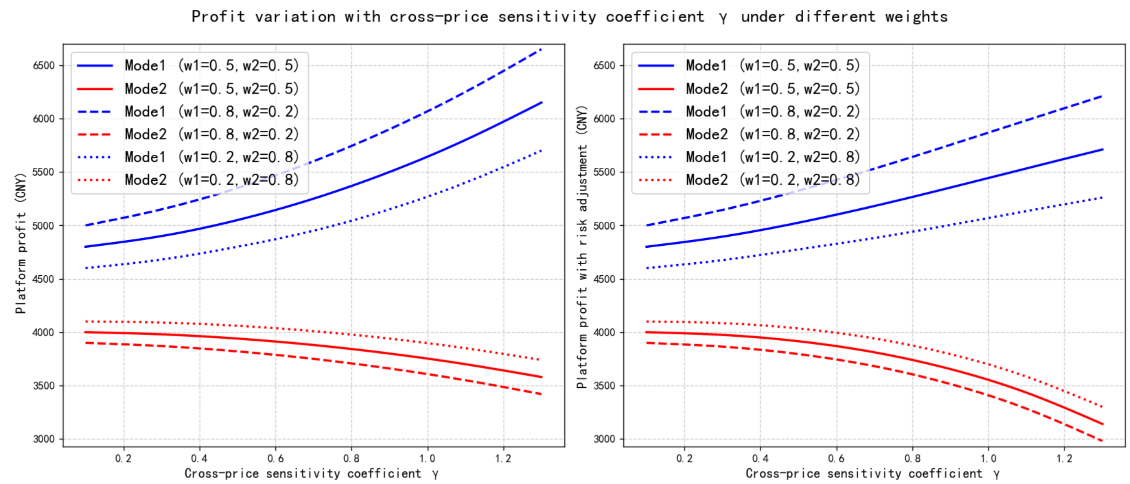

Figure 5. Profit variation of hybrid platforms with γ under different weights

In the risk-free scenario, the profit of Mode 1 rises at an accelerated pace with the increase of channel competition intensity γ . Self-built logistics provides differentiated high reliability for self-operated channels, alleviates price competition and boosts platform profits, and the advantages become more prominent as γ increases. The profit of Mode 2 declines at an accelerated pace with the increase of γ . The platform cannot provide differentiated services under the TPL led mode, and intensified channel competition erodes the demand of self-operated businesses and exacerbates competition among third-party sellers. The profit of Mode 1 is always higher than that of Mode 2, and the profit gap expands with the growth of γ . It proves that the self-built logistics led mode has greater advantages for hybrid platforms, and the advantages become more prominent as competition intensifies.

After introducing reliability loss penalties, all profit curves shift downward, and the decline range increases with the growth of γ . Fiercer competition leads to more severe damages caused by logistics uncertainties. The profit decline of Mode 2 is greater than that of Mode 1. Despite the overall profit reduction, Mode 1 still outperforms Mode 2, and risks do not change the conclusion that the self-built logistics led mode is superior. In regions with high γ values, the profit gap between the two modes is larger than that in the risk-free scenario. It demonstrates that hybrid platforms should firmly adopt the self-built logistics led mode in fiercely competitive and highly uncertain markets.

5. Conclusion and prospect

Classifying e-commerce platforms into resale platforms, marketplace platforms and hybrid platforms based on business model heterogeneity, this paper constructs game models incorporating consumers' perceived value of logistics services, and compares the two collaborative modes (self-built logistics led mode and TPL led mode). The main theoretical contributions are summarized as follows:

Platform Heterogeneity: Resale platforms prefer the self-built logistics led mode when service sensitivity is high; marketplace platforms tend to adopt the TPL led mode due to the lack of pricing power; hybrid platforms need to balance in-house service quality and third-party logistics costs, and their optimal mode depends on channel competition intensity.

Endogenization of Perceived Value: The consumer logistics service perception coefficient k is set as an endogenous parameter. When k exceeds a certain threshold, the profit advantages of the self-built logistics led mode are significantly enhanced, and the threshold varies across different types of platforms.

Risk Factors: The reliability loss aversion coefficient λ is introduced. Higher uncertainty in terminal delivery or stronger platform aversion to reliability losses makes the self-built logistics led mode relatively superior on account of its stronger controllability.

Game Modeling: Stackelberg models for the self-built logistics led mode and TPL led mode are constructed. The impact of leading power allocation is jointly regulated by platform type, service sensitivity and λ.

Resale platforms and marketplace platforms tend to select the TPL led mode in most parameter intervals, while hybrid platforms are more inclined to adopt the self-built logistics led mode. Such preference is continuously strengthened with the intensification of channel competition and the improvement of service sensitivity.

This paper still has some limitations. The demand function adopted in this paper is linear, and nonlinear or stochastic demand is not considered. The internal transfer price in Mode 1 is set as an exogenous variable. Follow-up research can introduce demand uncertainty and risk aversion, and explore horizontal transshipment and risk balancing strategies in multi-regional logistics networks.

References

[1] Guido, P., Nadia, S., & Chiara, V. (2025). A replicable framework to drive business model innovation enabled by Web3: A case study in the agrifood sector. *IEEE Transactions on Engineering Management, 73*, 818-831.

[2] Zampou, E., Manousakis, E., Argyropoulou, M., & Zissis, D. (2025). Exploring horizontal collaboration in home delivery operations: a case of Greek grocery retailers. *International Journal of Logistics Systems and Management, 51*(4), 576-598.

[3] Chen, L., Dong, T., Li, X., & Xu, X. (2025). Logistics engineering management in the platform supply chain: An overview from logistics service strategy selection perspective. *Engineering, 47*, 236-249.

[4] Yu, J., Zhou, C., & Leng, G. (2023). Is it always advantageous to establish self-built logistics for online platforms in a competitive retailing setting?. *IEEE Transactions on Engineering Management, 71*, 1726-1743.

[5] Zhang, W., Ji, L., & Wu, L. (2026). Self-built versus third-party smart logistics for e-commerce platforms: profit optimization under dual-channel sales models and price-matching strategies. *Operational Research, 26*(1), 10.

[6] Zhang J X, Mu J, Kang L. (2025). Research on e-commerce logistics mode decision considering brand differences and power structure. *Operations Research and Management, 34*(08), 15-21.

[7] Zhao X, Wang Y, Hu B. (2019). Research on collaborative distribution mechanism between e-commerce platform self-built logistics and third-party logistics enterprises. *Systems Engineering, 37*(02), 81-90.

[8] Tang, C., Zhao, S., Huang, T., & Goh, M. (2026). Dual-service combination optimization of manufacturing and logistics: models for self-managed and third-party logistics in cloud manufacturing. *Robotics and Computer-Integrated Manufacturing, 99*, 103178.
[9] Yu Y G, Guo D D, Zheng S M, Liu B, Liang L, Wang Q. (2024). Research on the impact of logistics service sharing in retailer-led supply chain. *Operations Research and Management, 33*(08), 141-147.
[10] Xu X Z, Yang Q, Ye J, Liu B, Chen W J. (2026). Reliability evaluation of logistics distribution network considering inventory and transportation costs. *Science Technology and Engineering, 26*(07), 2717-2723.
[11] Liu D, Jiang S. (2025). Cost allocation strategy of collaborative distribution considering customer differences under uncertain demand. *Industrial Engineering, 28*(01), 90-98.
[12] Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *The Rand Journal of Economics, 15*(4), 546-554.
[13] McGuire, T. W., & Staelin, R. (1983). An industry equilibrium analysis of downstream vertical integration. *Marketing Science, 2*(1), 161-191.

Appendix A

Appendix A1. Resale platform

Appendix A1.1. Self-built logistics led mode

In the third stage, R_p , ω and R_T are all determined. The platform selects p_r to maximize its own profit. The overall service reliability R is jointly provided by the platform and TPL, $R = w_1 R_P + w_2$, R_p denotes the service reliability provided by the platform's self-built logistics, R_T denotes the service reliability provided by TPL, $w_1, w_2 \in (0,1)$, and $w_1 + w_2 = 1$, which are the weight coefficients of service reliability for self-built logistics and TPL respectively.

Substitute the demand function into the platform's profit expression (Formula (A1)):

$$\pi_{ep} = (p_r - \omega)\left[a - bp_r + k\left(w_1 R_P + w_2 R_T\right)\right] - \tfrac{1}{2} z_P {R_P}^2 \tag{A1}$$

Since the term $-\frac{1}{2} z_P {R_P}^2$ is independent of p_r , solving for the optimal p_r is equivalent to maximizing $(p_r - \omega)\left[a - bp_r + k\left(w_1 R_P + w_2 R_T\right)\right]$. Calculate the first-order partial derivative with respect to p_r (Formula (A2)):

$$\frac{\partial \pi_{ep}}{\partial p_r} = a - 2bp_r + k\left(w_1 R_P + w_2 R_T\right) + b\omega = 0 \tag{A2}$$

The second-order partial derivative is $\frac{\partial^2 \pi_{ep}}{\partial {p_r}^2} = -2b$, which indicates that the first-order condition yields a unique maximum value (Formula (A3)):

$$p_r\left(R_P, R_T, \omega\right) = \frac{a + k(w_1 R_P + w_2 R_T) + b\omega}{2b} \tag{A3}$$

In the second stage, TPL knows R_p, ω , and anticipates that the platform will set prices according to Formula (A3). Substitute Formula (A3) into TPL's profit function (Formula (A4)):

$$\pi_{TPL} = \omega \cdot \frac{a - b\omega + k(w_1 R_P + w_2 R_T)}{2} - \tfrac{1}{2} z_T {R_T}^2 \tag{A4}$$

TPL selects R_T to maximize the above profit function. Calculate the first-order partial derivative with respect to R_T (Formula (A5)):

$$\frac{\partial \pi_{TPL}}{\partial R_T} = \frac{\omega k w_2}{2} - z_T R_T = 0 \tag{A5}$$

The second-order partial derivative is $\frac{\partial^2 \pi_{TPL}}{\partial {R_T}^2} = -z_T$, so the first-order condition yields the optimal reaction function (Formula (A6)):

$$R_T\left(R_P, \omega\right) = \frac{\omega k w_2}{2 z_T} \tag{A6}$$

In the first stage, as the game leader, the platform anticipates that TPL will make decisions according to Formula (A6), and the platform itself will set prices according to Formula (A3) in the third stage. Therefore, the platform substitutes $R_T\left(R_P, \omega\right) = \frac{\omega k w_2}{2 z_T}$ and the expression of p_r into its profit function to obtain an objective function with R_p and ω as decision variables.

Firstly, substitute Formula (A6) into the demand function to derive total demand (Formula (A7)):

$$Q = \frac{a - b\omega + k w_1 R_P + \frac{k^2 {w_2}^2 \omega}{2 z_T}}{2} \tag{A7}$$

where Q represents total demand, which will be used hereinafter.

Substitute Formula (A7) into the retail price expression (Formula (A3)) to obtain the retail price (Formula (A8)):

$$p_r = \frac{a + k w_1 R_P + \frac{k^2 {w_2}^2 \omega}{2 z_T} + b\omega}{2b} \tag{A8}$$

The platform's profit is expressed as Formula (A9):

$$\pi_{ep} = (p_r - \omega) Q - \frac{1}{2} z_P {R_P}^2 \tag{A9}$$

Substitute $p_r - \omega$ and Q with Formula (A7) and Formula (A8) respectively, and let $M = a - b\omega + \frac{k^2 {w_2}^2 \omega}{2 z_T}$. The profit function is rewritten as Formula (A10):

$$\pi_{ep} = \frac{(M + k w_1 R_P)^2}{4b} - \frac{1}{2} z_P {R_P}^2 \tag{A10}$$

The platform aims to maximize Formula (A10) by selecting $R_P \geq 0$ and $\omega \geq 0$. This is a bivariate optimization problem. Calculate partial derivatives with respect to R_p and ω respectively and set them equal to zero, and we obtain: ${R_P}^* = \frac{k w_1 M}{2 b z_P - k^2 {w_1}^2}$, $z_T = \frac{k^2}{2b}$.

The final results are derived as follows: ${R_T}^{*(1)} = \frac{k w_2 \omega}{2 z_T}$, ${p_r}^{*(1)} = \omega + \frac{z_P M}{2 b z_P - k^2 {w_1}^2}$, ${\pi_{ep}}^{*(1)} = \frac{z_P M^2}{2\left(2 b z_P - k^2 {w_1}^2\right)}$, ${\pi_{TPL}}^{*(1)} = \frac{\omega b z_P M}{2 b z_P - k^2 {w_1}^2} - \frac{\omega^2 {w_2}^2 k^2}{8 z_T}$, $\pi^* = {\pi_{ep}}^* + {\pi_{TPL}}^*$.

Appendix A1.2. TPL led mode

Given R_P , R_T and ω, the platform selects p_r to maximize net profit (Formula (A11)):

$$\pi_{ep} = (p_r - \omega)\left[a - bp_r + k\left(w_1 R_P + w_2 R_T\right)\right] - \tfrac{1}{2} z_P {R_P}^2 \tag{A11}$$

Calculate the first-order derivative with respect to p_r (Formula (A12)):

$$\tfrac{\partial \pi_{ep}}{\partial p_r} = a - 2bp_r + k\left(w_1 R_P + w_2 R_T\right) + b\omega = 0 \tag{A12}$$

Solve the equation to obtain the optimal reaction function (Formula (A13)):

$$p_r\left(R_P, R_T, \omega\right) = \tfrac{a+k(w_1 R_P + w_2 R_T)+b\omega}{2b} \tag{A13}$$

In the second stage, the platform knows ω and R_T , and anticipates that retail prices will be set according to Formula (A13). Substitute Formula (A13) into the platform's profit function (Formula (A14)), and the platform selects R_P to maximize its profit at this stage.

$$\pi_{ep} = \tfrac{\left[a-b\omega+k(w_1 R_P + w_2 R_T)\right]^2}{4b} - \tfrac{1}{2} z_P {R_P}^2 \tag{A14}$$

Formula (A14) indicates that the platform profit is only related to R_P as well as the known ω and R_T . Calculate the first-order partial derivative with respect to R_P (Formula (A15)):

$$\tfrac{\partial \pi_{ep}}{\partial R_P} = \tfrac{k\left[a-b\omega+k(w_1 R_P + w_2 R_T)\right]}{2b} - z_P R_P = 0 \tag{A15}$$

The solution is derived as (Formula (A16)):

$$R_P\left(R_T, \omega\right) = \tfrac{k w_1 (a - b\omega + k w_2 R_T)}{2b z_P - k^2 {w_1}^2} \tag{A16}$$

As the game leader, TPL anticipates that the platform will select R_P according to Formula (A16) and finally set prices in line with Formula (A18). TPL aims to maximize its own profit by choosing ω and R_T . Substitute Formula (A13) and Formula (A16) into the demand function, and we obtain Formula (A17):

$$Q = \tfrac{b z_P}{2b z_P - k^2 {w_1}^2}\left(a - b\omega + k w_2 R_T\right) \tag{A17}$$

Substitute Formula (A17) into TPL's profit function (Formula (A18)):

$$\pi_{TPL} = \tfrac{b z_P \omega}{2b z_P - k^2 {w_1}^2}\left(a - b\omega + k w_2 R_T\right) - \tfrac{1}{2} z_T {R_T}^2 \tag{A18}$$

TPL needs to maximize profit by selecting ω and R_T simultaneously. Calculate partial derivatives with respect to ω and R_T respectively, and the solutions are: $R_T = \frac{\omega b z_P k w_2}{z_T\left(2b z_P - k^2 w_1^2\right)}$, $\omega = \frac{a + k w_2 R_T}{2b}$.

Combine the two equations to get: $R_T = \frac{z_P k a w_2}{2 z_T\left(2b z_P - k^2 {w_1}^2\right) - z_P k^2 {w_2}^2}$, $\omega = \frac{a\left(2b z_P - k^2 {w_1}^2\right) z_T}{b z_T\left(2b z_P - k^2 {w_1}^2\right) - z_P k^2 {w_2}^2}$.

Substitute the solved ω and R_T into relevant expressions to derive all equilibrium variables: ${R_T}^{*(2)} = \frac{z_P k a w_2}{2z_T(2bz_P - k^2{w_1}^2) - z_P k^2 {w_2}^2}$, ${\omega}^{*(2)} = \frac{a + kw_2 R_T}{2b}$, ${R_P}^{*(2)} = \frac{akw_1}{2(2bz_P - k^2{w_1}^2)}$, ${\pi_{ep}}^{*(2)} = \frac{a^2 z_P z_T}{8(2bz_P - k^2{w_1}^2)z_T - 4z_P k^2 {w_2}^2}$, ${\pi_{TPL}}^{*(2)} = \frac{a^2 z_P z_T[(2bz_P - k^2{w_1}^2)z_T - z_P k^2 {w_2}^2]}{[(4bz_P - 2k^2{w_1}^2)z_T - z_P k^2 {w_2}^2]^2}$

Appendix A2. Marketplace Platform: Self-built Logistics Led Mode

Stage 1: As the game leader, the platform anticipates that TPL will select R_T according to Formula (A19), and sellers will set p_m and Q as mentioned above. The platform selects $R_P \geq 0$, $\omega \geq 0$ and $F \geq 0$ to maximize its own profit. Firstly, substitute Formula (A19) into the total logistics service reliability R (Formula (A20)):

Calculate the partial derivative with respect to R_P : $\frac{\partial \pi_T}{\partial R_T} = \omega \cdot \frac{kw_2}{2} - z_T R_T = 0$. The solution is derived as (Formula (A19)):

$$R_T = \frac{\omega K w_2}{2z_T} \tag{A19}$$

$$R = w_1 R_P + \frac{k{w_2}^2}{2z_T}\omega \tag{A20}$$

Substitute Formula (A20) into the demand function (Formula (A21)):

$$Q = \frac{1}{2}\left[a + kw_1 R_P + \frac{k^2{w_2}^2\omega}{2z_T} - b(r+f)\right] \tag{A21}$$

Substitute Formula (A21) into the platform's profit function to obtain Formula (A22):

$$\pi_{ep} = \frac{1}{2}(r+f-\omega)\left[a + kw_1 R_P + \frac{k^2{w_2}^2\omega}{2z_T} - b(r+f)\right] - \frac{1}{2}z_P{R_P}^2 \tag{A22}$$

The platform aims to maximize π_{ep} . Calculate the first-order partial derivatives with respect to R_P and ω respectively and set them equal to zero (Formula (A23)):

$$\frac{\partial \pi_{ep}}{\partial R_P} = \frac{kw_1}{2}(r+f-\omega) - z_P R_P = 0 \tag{A23}$$

The solutions are Formula (A24) and Formula (A25):

$$R_P = \frac{Kw_1}{2z_P}(r+f-\omega) \tag{A24}$$

$$\frac{\partial \pi_{ep}}{\partial \omega} = -Q + \frac{1}{2}(r+f-\omega)\frac{k^2{w_1}^2}{2z_T} = 0 \tag{A25}$$

Stage 2: After observing R_P , ω and F set by the platform, TPL anticipates that sellers will set the retail price p_m and total demand Q accordingly. Substitute the above results into TPL's profit function to obtain Formula (A26):

$$\pi_{TPL} = \omega \cdot \frac{a+k(w_1 R_P + w_2 R_T) - b(r+f)}{2} - \frac{1}{2} z_T {R_T}^2 \tag{A26}$$

Stage 3: Sellers' pricing is determined by Formula (A25) and Formula (A27).
The solution is derived as (Formula (A27)):

$$Q = (r + f - \omega) \frac{k^2 {w_1}^2}{4 z_T} \tag{A27}$$

The final equilibrium results are obtained as follows: ${R_T}^{*(3)} = \frac{\omega k w_2}{2 z_T}$, ${R_P}^{*(3)} = \frac{k w_1 (M - b\omega)}{4 b z_P - k^2 {w_1}^2}$, where $M = a + \omega\left(\frac{k^2 w_2^2}{2 z_T} - b\right)$, ${\pi_{ep}}^{*(3)} = \frac{z_P \left[a + \omega\left(\frac{k^2 {w_2}^2}{2 z_T} - 2b\right)\right]^2}{2\left(4 b z_P - k^2 {w_1}^2\right)}$, ${\pi_{TPL}}^{*(3)} = \frac{\omega\left(2 b z_P - k^2 {w_1}^2\right)\left[a + \omega\left(\frac{k^2 {w_2}^2}{2 z_T} - 2b\right)\right]}{2\left(4 b z_P - k^2 {w_1}^2\right)} - \frac{\omega^2 k^2 {w_2}^2}{8 z_T}$.