

Analysis of delivery strategies for dual-channel retail in China's home furnishing industry

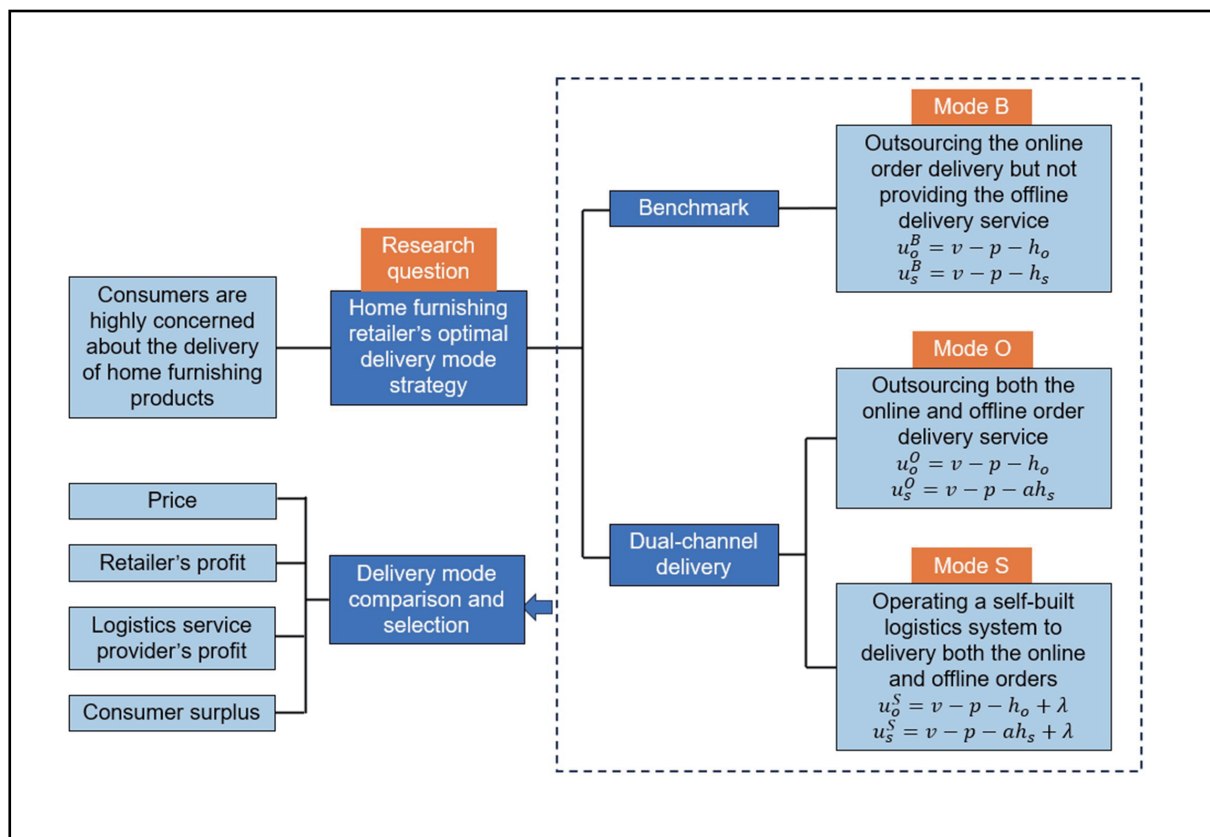
Yuwen Da, Jiashu Cui , and Qinglong Gou

School of Management, University of Science and Technology of China, Hefei 230026, China

✉ Correspondence: Jiashu Cui, E-mail: sm21204117@mail.ustc.edu.cn

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Graphical abstract



The research framework of the delivery strategies for a dual-channel home furnishing retailer.

Public summary

- We develop an analytical framework to model the consumer's utility and the dual-channel home furnishing retailer's trade-off under different delivery strategies.
- We derive the optimal pricing decisions and profits for the dual-channel home furnishing retailer and the third-party logistics provider under different delivery strategies.
- We examine the optimal delivery strategy for the retailer and analyze the related factors.
- We explore the impact of different delivery strategies on the retail price, logistics provider, and consumer surplus.

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Supporting Information

Abstract: Owing to the unique characteristics of home furnishing products, dual-channel delivery constitutes a crucial part of the consumer experience, prompting domestic home furnishing retailers in China to regard delivery as a key strategic priority. According to the different service providers and usage channels of logistics, home furnishing retailers can adopt multiple delivery strategies. Specifically, we explore three alternative delivery modes: outsourcing the online order delivery to a third-party logistics (3PL) provider but not providing the offline delivery service (Mode B); outsourcing both online and offline delivery services to a 3PL provider (Mode O); and organizing a self-built logistics system for the delivery of both online and offline orders (Mode S). Constructing a game-theoretic model involving a dual-channel home furnishing retailer and a 3PL provider, this paper explores the optimal pricing strategies and delivery modes under different conditions. The results reveal that the retailer can strategically abandon the online market by adjusting pricing or logistics service decisions under certain circumstances. By comparing the equilibrium results of different modes, we find that although improving the delivery service levels is a current trend in the home furnishing industry, such service improvement paired with higher retail prices does not always yield benefits for the retailer. Even consumers do not always prefer a high-level delivery service. The best delivery mode depends on the dual impact of consumers' perceptions of online and offline shopping experiences, as well as logistics costs. Furthermore, supply chain members' preferences for delivery modes are mostly contradictory. Only when the cost of self-built logistics is high and customers heavily rely on the offline delivery service can a multi-win outcome be achieved.

Keywords: dual-channel retailing; self-built logistics; logistics service outsourcing; delivery mode; home furnishing industry

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1 Introduction

In recent years, with the rapid advance of China's urbanization, the continuous growth of the urban population has driven a new demand for housing and thus provided a broad space for the development of the home furnishing industry. Due to the widespread use of e-commerce and electronic payments, people have become accustomed to a digital lifestyle, and the online channel has become the main channel for home furnishing consumption. However, it is difficult for the online channel to maintain close contact with consumers in personalized customization and after-sales services, so currently the offline store still cannot be ignored. Consequently, under the wave of China's New Retail, China's home furnishing sales model has been upgraded to a dual-channel structure with deep integration of online and offline channels^[1].

For consumers, the greatest difference between home furnishing products and ordinary products is that home furnishing products are truly large in size, extremely heavy in weight, and easily damaged, making it difficult to pick up the products on their own. Hence, consumers heavily rely on logistics transportation even when purchasing offline. According to a report on China's household service industry in

2022^[2], the share of service-sensitive consumers in household appliance and furniture consumption stands at 76%. Among all service types, logistics is a top concern for consumers, ranking as the third most influential decision factor behind product quality and design and above product price. This means that the delivery of home furnishings is the core factor affecting consumers' experience. A sound service system can help home furnishing enterprises expand the market, while low-quality delivery will reduce customer satisfaction and damage customer relationships^[3,4].

In response to consumer demand, unlike ordinary products, home furnishing retailers often have to provide logistics services not only in online channels but also in offline channels. In China, the retailers have two main ways to manage their dual-channel logistics operations. One is outsourcing the delivery of online and offline orders to large-item logistics contractors. For example, in 2019, Suofeiya and Deppon Express signed a contract to carry out deep cooperation in transportation and delivery^①. The other way is building a self-logistics network for dual-channel order delivery. For instance, large

① https://www.sohu.com/a/331088615_769687.

home furnishing enterprises including Suning and Easyhome have established their own logistics network layouts with strong distribution capability and high coverage of store outlets, thereby achieving success in the field of self-built logistics^[1,2].

Between these two options, logistics outsourcing saves the cost of building a logistics system, but it also leads to a relatively low service quality. For example, consumers may face the separation of transportation and installation. Due to the particularity of home furnishing products, consumers often need installation services after the products are delivered^[3]. In most cases, although transportation and delivery are outsourced, installation is still the responsibility of the retailer. Many home furnishing brands that outsource logistics, such as Gree[®] and KUCA[®], require consumers to make separate appointments for on-site installation services after receiving products, which leads to trouble and inconvenience for consumers. Even though some logistics companies, such as JD Logistics, can provide installation services while delivering products[®], there are still issues with unprofessional operations. In contrast, when organizing a self-built logistics system, the retailer is responsible for both transportation and installation services, which can better connect various links and achieve full coordination. Moreover, the retailer is more familiar with its own products and thus can provide a more professional after-sales service. For instance, Haier established RRS logistics for product distribution and delivery. Through logistics scheduling, during the product delivery process, the firm arranges professional technical personnel to provide on-site installation services simultaneously[®]. Therefore, through self-built logistics, the home furnishing retailer can better control the quality of the end services. However, building a massive logistics network incurs enormous costs and requires a sufficiently large business scale and high resource management ability^[6].

Motivated by the above business observations, we aim to explore how dual-channel home furnishing retailers should choose their delivery strategies and the corresponding impact of different delivery modes. Specifically, we discuss the following questions. (i) Is providing dual-channel logistics services really beneficial? (ii) How should the home furnishing retailer choose an optimal delivery mode? (iii) What impact does the delivery strategy of a home furnishing retailer have on the price and interests of supply chain members?

To address these questions, this paper establishes a game-theoretic model involving a dual-channel home furnishing retailer and a third-party logistics (3PL) provider, and analyzes their pricing decisions as well as the delivery mode choice of the retailer. Taking the scenario of not providing an offline delivery service (Mode B) as a benchmark, which is the delivery mode adopted by most ordinary products, we further consider two dual-channel delivery modes: outsourcing the dual-channel delivery to a logistics provider (Mode O) and organizing a self-built logistics network for the order delivery of both channels (Mode S). By comparing the results of different modes, we obtain the retailer's optimal decision and the impact of delivery modes. We find that providing dual-channel logistics services can increase the retail price but is not always beneficial for both the retailer and consumers. The

home furnishing retailer's optimal delivery strategy and consumer group's preferences depend on the consumers' perceptions of online and offline shopping experiences as well as the logistics costs. Under certain conditions, the supply chain members' preferences are consistent, and a multi-win outcome can be obtained.

The main contributions of our study are as follows. In terms of practice, our work explores the optimal delivery strategies of home furnishing retailers under different conditions, which can provide managerial insights into the operation of the home furnishing industry. In terms of theory, although there have been many studies on dual-channel retailing, most of them ignore the important role of logistics services in dual-channel order delivery, especially in the home furnishing industry, which pays extra attention to the quality of delivery services. Therefore, by investigating the delivery modes of the dual-channel home furnishing industry, this study enriches the research related to dual-channel retailing as well as logistics service operations.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 develops the model framework and introduces the notations. The equilibrium results for the different delivery modes are presented in Section 4. In Section 5, we compare the prices, profits, and surplus of the three delivery modes, and discuss the optimal delivery strategy of the retailer. Finally, Section 6 concludes the paper with a brief summary.

2 Literature review

Three research streams are closely related to this study, namely, dual-channel retailing, home furnishing industry logistics, and delivery modes in e-commerce logistics.

Current research on dual-channel retailing mainly focuses on the channel selection strategies, pricing strategies, and service strategies. In terms of channel comparison, by analyzing the operation data of supermarket chains, Pozzi^[7] found that the online channel can effectively reduce consumers' travel costs and divert business from rivals, thereby increasing the brick-and-mortar retailer's market competitiveness. However, Yoo and Lee^[8] showed that when consumers have preference heterogeneity, the online channel may instead result in losses for retailers. With the trend of channel integration in recent years, many scholars have further studied the mutual influence between channels and the optimal channel strategy of enterprises. Gao and Su^[9] focused on the phenomenon of online shopping and offline pickup and investigated the impact and applicable products of BOPS. Jing^[10] considered the showrooming effect on cross-channel purchases and analyzed its influence on intensifying competition, launching exclusive products, and return policies. Based on the phenomenon that

① <http://www.chinawuliu.com.cn/zixun/202203/25/573784.shtml>.

② <https://new.qq.com/rain/a/20201226A0LAF800>.

③ https://gree.tmall.com/p/rd311947.htm?spm=a1z10.1-b-s.w5001-25200600920.13.7b408705ykbZ38&scene=taobao_shop.

④ https://kukamf.tmall.com/shop/view_shop.htm?spm=pc_detail.27183998/evo365560b447257.202202.2.12ee7dd68qEKM1.

⑤ <https://www.jdl.com/news/3139/content01246?type=0>.

⑥ <https://www.haierhui.com/helpcenter.php?id=21>.

physical stores serve as warehouses for the online channel, Tang et al.^[11] discussed competing firms' optimal retail channel choices. In addition to channel strategies, the pricing strategies have also been a popular issue in dual-channel research, which mainly centers on differential pricing between online and offline channels. Balakrishnan et al.^[12] argued that the channel pricing differential can stimulate consumers' cross-channel purchases, leading to intensified competition between channels and in turn eroding the profit of the original offline channel. Panda et al.^[13] demonstrated that consumers' channel preference exacerbates the price competition between channels: When consumers' offline channel preference is low, the manufacturer will set a higher online price; otherwise, the offline price is higher. Kim and Chun^[14] suggested that the price difference between channels depends on how easy it is for consumers to search for channel price information. Besides, some scholars discussed the price, demand, and profit from the perspective of service quality. Jiang et al.^[15] constructed a retailer-dominated dual-channel supply chain and showed that the service level of the brick-and-mortar retailer affects the pricing strategy of the supply chain. Zhang et al.^[16] argued that compared to not providing store services, providing store services can always increase the retailer's profit. The existing literature on dual-channel retailing has discussed many operational issues, but little attention has been given to dual-channel logistics. Our paper innovatively considers a third-party logistics firm and the retailer's self-built logistics in dual-channel retailing. By constructing a game-theoretic model between a dual-channel retailer and a third-party logistics (3PL) provider, our work explores the interaction between the supply chain members' pricing and delivery strategies in dual-channel home furnishing retailing.

The literature related to home furnishing logistics mostly concentrates on the last-mile delivery path problem. Ferreira et al.^[17] proposed a VRP (vehicle routing problem) model for furniture delivery and assembly. Luo et al.^[18] developed a distribution and delivery system for customized furniture and designed a new HGA-VNS algorithm to optimize the vehicle path planning scheme. Mohammadi et al.^[19] designed a hybrid particle swarm optimization algorithm to integrate the production process with the delivery process, which can improve customer satisfaction without significantly increasing the total operating cost of the system. Based on the separation of delivery and installation, Qiu et al.^[20] determined the optimal delivery routes for vehicles and the optimal service routes for technicians to minimize the total travel distance. Tunyaplin and Chanpuypetch^[21] built a performance measurement system (PMS) for home furniture retailers to monitor and control the quality of their last-mile delivery service. Some studies further discussed the cooperation in the home logistics industry. For example, Audy et al.^[22] discussed the transportation collaboration among several companies to reduce costs and delivery time. Alnahhal et al.^[23] used a furniture company in Germany as a case study and proposed an optimal distribution scheme based on the pricing of logistics providers and the geographical distribution of customers. Different from these studies, our work does not focus on the delivery programming problem but investigates the optimal delivery strategy of a dual-channel home furnishing retailer

from a more macroscopic perspective, i.e., whether the retailer should provide a dual-channel delivery service and whether the delivery service is outsourced or self-built.

Many studies have discussed the selection of delivery modes in the logistics supply chain from different perspectives. Zailani et al.^[24] utilized a large amount of data to investigate the factors affecting the extent of logistics outsourcing, finding that the lack of human and physical asset capabilities, as well as transaction uncertainty, are the core factors. Lou et al.^[25] explored the logistics service outsourcing choices in a retailer-led supply chain and designed a cost-sharing contract to achieve a win-win outcome between the retailer and the 3PL provider. Du et al.^[26] discussed the merchant's decision of whether to adopt a self-built platform and self-delivery in the food delivery industry. In addition, many studies have extended delivery mode decisions to more complex supply chain scenarios with competitive or cooperative relationships. Li et al.^[27] compared the services undertaken or outsourced by the manufacturer and the retailer in a supply chain and analyzed the optimal service channel. Wang et al.^[28] analyzed whether a manufacturer should apply the retailer's logistics system when there is competition between the manufacturer's direct channel and the retailer's resale channel. Li et al.^[29] and Yu et al.^[30] explored the self-built logistics decisions of e-commerce platforms from various perspectives and obtained the dominant conditions for self-built logistics. Their studies are based on a similar scenario: The platform's products compete with the products of retailers on the platform, and retailers can use the platform's self-built logistics. Similarly, Qin et al.^[31] also discussed the issue of platform logistics, but they assumed that the platform already has its own logistics system and analyzed whether logistics service sharing should be carried out with retailers. Our contribution to this literature stream is that we extend the delivery mode issue to the home furnishing industry. These existing studies concentrate on the delivery modes in a single online channel, while we explore the dual-channel delivery due to the particularity of home furnishing products, filling the research gap and enriching the related literature.

3 Model framework

Consider a home furnishing retailer selling products through both online and offline channels. Similar to Qiu et al.^[32], we assume that the retailer adopts a uniform price policy between channels. This assumption is very common in the home furnishing industry. For example, to avoid cross-channel purchases due to price differences, many companies, such as Cheers^①, Suning, Haier, and Midea^②, have promoted the policy of uniform pricing in online and offline channels in recent years. Therefore, we use p to denote the retail price in both channels. For the delivery of orders, we consider a benchmark mode and two dual-channel delivery modes: (i) outsourcing the online delivery to a 3PL provider but not providing the offline delivery service (Mode B); (ii) outsourcing all the delivery services to a 3PL provider (Mode O); and (iii) operating a self-built logistics network for

① sz.jiaju.sina.com.cn/zixun/20191025/6593420599270640447.shtml.

② <https://www.jiemian.com/article/5472044.html>.

dual-channel order delivery (Mode S). In Modes B and O, the 3PL provider charges a unit delivery fee ω for each order. In Mode S, the retailer undertakes the unit delivery cost ρ and the fixed cost of logistics network construction F .

Consumers' valuation of the product is v , which is heterogeneous and follows a uniform distribution on $[0,1]$. Consumers incur costs for both online and offline channel purchases. When shopping online, consumers incur search costs, mismatch costs, etc., which are collectively referred to as online hassle cost h_o . When shopping offline, consumers incur travel costs, picking up costs, etc., which are collectively referred to as offline hassle cost h_s . Given the widespread popularity of e-commerce and electronic payments, most people are already very familiar with online shopping. However, the experience of offline purchasing is influenced by factors such as distance and vehicles, which vary greatly among people. Accordingly, we suppose that the online hassle cost h_o is homogeneous, while the offline trouble cost h_s obeys a uniform distribution on $[0,1]$.

In benchmark Mode B, i.e., not providing offline order delivery services, consumers have to carry the home furnishing products by themselves, and thus they will bear the full offline hassle cost h_s . The utility of purchasing in the offline channel is $u_s^B = v - p - h_s$. Meanwhile, if consumers purchase online, their utility is $u_o^B = v - p - h_o$.

Compared with Mode B, outsourcing the offline delivery service (Mode O) reduces the hassle cost of offline purchases for consumers. Let ah_s ($0 < a < 1$) denote the hassle cost of offline purchasing when the retailer provides an offline delivery service, where a measures the dependence of consumers on the offline delivery service. A smaller a indicates that providing offline delivery has a greater utility improvement for consumers; that is, consumers are more dependent on the offline delivery service. Consequently, in Mode O, the utility of consumers buying offline is $u_s^O = v - p - ah_s$, and the utility of purchasing online is still $u_o^O = v - p - h_o$.

Unlike outsourcing logistics services, when the retailer builds its own logistics network for order delivery, the quality of logistics will be higher because of more integrated and professional services. Hence, in Mode S, the consumers' utility will increase. Meanwhile, since the offline delivery service still exists, the hassle cost of offline channel shopping for consumers is still ah_s , which is the same as that in Mode O. Therefore, the consumers' utility of purchasing offline turns

out to be $u_s^S = v - p - ah_s + \lambda$, while that of purchasing online is $u_o^S = v - p - h_o + \lambda$, where λ is the retailer's additional self-built delivery service quality.

It is supposed that consumers have no special preference for the two channels and only purchase in the way with larger utility. Meanwhile, consumers are motivated to make a purchase only when the utility they obtain is not less than zero. Hence, the premise that consumers choose to purchase in the offline channel is $u_s^i \geq \max\{u_o^i, 0\}$, and the condition for online purchasing is $u_o^i \geq \max\{u_s^i, 0\}$. Here, the superscript $i = B, O$, and S , which denote Mode B, Mode O, and Mode S, respectively. Referring to the analytical method of Qiu et al.^[32], we use h_s and v to denote the horizontal and vertical axes, respectively. Consumer demand is then derived as shown in Fig. 1, where the marked areas represent the market demand of different channels in each mode. We can see that there exists a threshold of offline shopping hassle cost in each delivery mode, where consumers with offline shopping hassle cost above this threshold will buy online and those with lower offline shopping hassle cost will buy offline. Furthermore, this threshold increases when providing an offline delivery service. Providing offline delivery improves consumers' utility of offline shopping, and thus some consumers switch to the offline channel, thereby resulting in the effect of expanding offline demand and shrinking online demand.

The sequence of events is as follows. First, the retailer decides the delivery mode. Then, if the retailer chooses Mode B or Mode O, the 3PL provider determines the unit product delivery fee ω^i . Finally, the retailer decides the retail price p^i , and if the retailer chooses Mode S, it also needs to determine its service level λ . All the parameters involved are shown in Table 1. To make the results of this paper more analytical, we assume that there always exist consumers who prefer online shopping, i.e., $h_o/a \leq 1$. In addition, due to the current development needs of e-commerce, the retailer needs to ensure a certain online demand, so the retail price satisfies the condition $p^i + h_o \leq 1$ ($i = B, O$) and $p^S + h_o - \lambda \leq 1$.

4 Model analysis

In this section, we derive the equilibrium prices of the retailer and the 3PL provider in each mode.

4.1 Mode B

In Mode B, offline orders are picked up by consumers, and

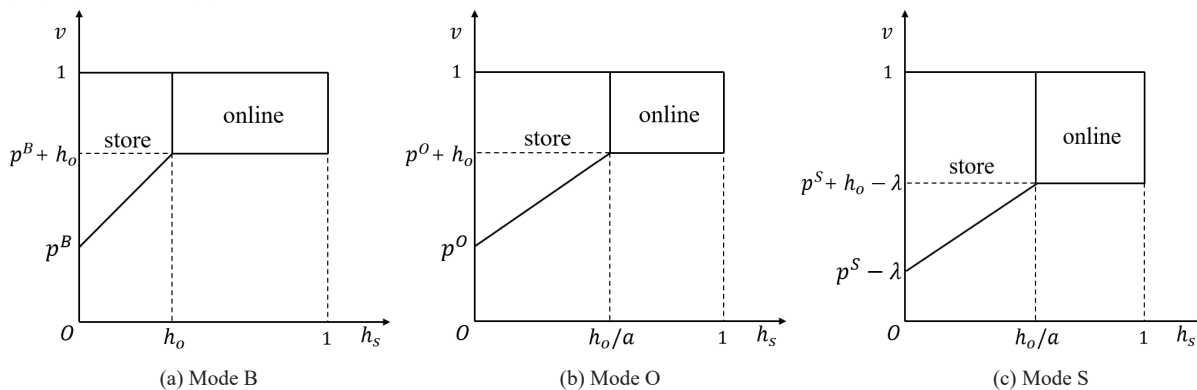


Fig. 1. Consumer demand in different modes.

Table 1. Notation description.

Notation	Meaning
u_s^i, u_o^i	Utility of consumer purchases in offline and online channels
v	Consumers' valuation of the product
p^i	Product retail price
ω^i	Unit delivery fee of the 3PL provider
h_s	Hassle cost of offline purchase
h_o	Hassle cost of online purchase
a	Consumers' dependence on the offline delivery service
λ	Retailer's additional delivery service quality
ρ	Unit delivery cost of self-built logistics in Mode S
F	Fixed cost of self-built logistics network in Mode S
D_s^i, D_o^i	Demand in offline and online channels
π_R^i, π_L^i	Profits of the retailer and the 3PL provider
CS^i	Consumer surplus in each mode

online orders are delivered by the 3PL provider. Both the retailer and the online logistics service provider aim to maximize their profit. The retailer's profit function is

$$\pi_R^B = p^B D_s^B + (p^B - \omega^B) D_o^B, \quad (1)$$

and the profit function of the online logistics service provider is

$$\pi_L^B = \omega^B D_o^B. \quad (2)$$

Here, $D_s^B = (2 - 2p^B - h_o)h_o/2$, $D_o^B = (1 - h_o)(1 - p^B - h_o)$, and the retailer's price satisfies $0 \leq p^B \leq 1 - h_o$. To focus on the retailer's delivery decision, the logistics cost of the 3PL provider is normalized to 0. This simplification does not change the analysis of management insights. Using backward induction, we can obtain the equilibrium results in Proposition 1.

Proposition 1. When the retailer does not provide an offline delivery service, the equilibrium results are shown as follows.

(i) When $0 \leq h_o \leq \sqrt{3} - 1$, $\omega^{B*} = \frac{1}{2} - \frac{h_o^2}{4(1-h_o)}$, $p^{B*} = \frac{3(1-h_o)}{4} + \frac{h_o^2}{8}$, and the corresponding

$$\begin{aligned} D_s^{B*} &= \frac{h_o(2 + 2h_o - h_o^2)}{8}, \\ D_o^{B*} &= \frac{(1 - h_o)(2 - 2h_o - h_o^2)}{8}, \\ \pi_R^{B*} &= \frac{h_o^4 - 28h_o^3 + 32h_o^2 - 8h_o + 4}{64}, \\ \pi_L^{B*} &= \frac{(2 - 2h_o - h_o^2)^2}{32}, \\ CS^{B*} &= \frac{-21h_o^4 + 28h_o^3 + 48h_o^2 - 24h_o + 12}{384}. \end{aligned}$$

(ii) When $\sqrt{3} - 1 < h_o \leq 1$, ω^{B*} can take any value greater than 0, $p^{B*} = 1 - h_o$, and the corresponding $D_s^{B*} = \frac{h_o^2}{2}$, $D_o^{B*} = 0$, $\pi_R^{B*} = \frac{h_o^2(1-h_o)}{2}$, $\pi_L^{B*} = 0$, $CS^{B*} = \frac{h_o^3}{6}$.

It can be found that the optimal price and the corresponding profits in Mode B are determined by the online hassle cost h_o . When h_o is very large, consumers have a weak willingness to purchase online, and the online market potential is very small. Therefore, the retailer will raise the retail price until the online demand drops to zero, abandoning the online market directly. In this way, the retailer can monopolize the supply chain profit without giving the 3PL provider any revenue. When h_o is not very large, both the offline and online markets operate normally, and the related detailed analysis can be found in Section 4.4.

4.2 Mode O

In Mode O, the retailer outsources the online and offline order delivery to a 3PL provider and pays the logistic firm delivery fee. The retailer's profit function is

$$\pi_R^O = (p^O - \omega^O)(D_s^O + D_o^O), \quad (3)$$

and the profit function of the 3PL provider is

$$\pi_L^O = \omega^O(D_s^O + D_o^O). \quad (4)$$

Here, $D_s^O = (2 - 2p^O - h_o)h_o/(2a)$, $D_o^O = (1 - h_o/a)(1 - p^O - h_o)$, and the retailer's price satisfies $0 \leq p^O \leq 1 - h_o$. In the same vein as Proposition 1, we can obtain the equilibrium results of Mode O in Proposition 2.

Proposition 2. When a retailer outsources the online and offline delivery services, the equilibrium results are shown as follows.

(i) When $0 \leq h_o \leq \hat{h}_o$, $\omega^{O*} = \frac{h_o^2}{4a} + \frac{1-h_o}{2}$, $p^{O*} = \frac{3h_o^2}{8a} + \frac{3(1-h_o)}{4}$, and the corresponding

$$\begin{aligned} D_s^{O*} &= \frac{-3h_o^3 + 2ah_o(1+h_o)}{8a^2}, \\ D_o^{O*} &= \frac{(a-h_o)(2a(1-h_o)-3h_o^2)}{8a^2}, \\ \pi_R^{O*} &= \frac{(2a(1-h_o)+h_o^2)^2}{64a^2}, \\ \pi_L^{O*} &= \frac{(2a(1-h_o)+h_o^2)^2}{32a^2}, \\ CS^{O*} &= \frac{-45h_o^4 + 52ah_o^3 + 12a(1+a)h_o^2 - 24a^2h_o + 12a^2}{384a^2}. \end{aligned}$$

(ii) When $\hat{h}_o < h_o \leq 1$, $\omega^{O*} = 1 - h_o$, $p^{O*} = 1 - h_o$, and the corresponding $D_s^{O*} = \frac{h_o^2}{2a}$, $D_o^{O*} = 0$, $\pi_R^{O*} = 0$, $\pi_L^{O*} = \frac{h_o^2(1-h_o)}{2a}$, $CS^{O*} = \frac{h_o^3}{6a}$. Here,

$$\hat{h}_o = (2\sqrt{2} - 3)a + \sqrt{(17 - 12\sqrt{2})a^2 - 2(2\sqrt{2} - 3)a}.$$

Similar to Mode B, when the online hassle cost h_o is large and the online channel is unattractive, the retailer will implement a high price strategy to ensure high margin profit and give up the online market. However, there are also some differences from Mode B. First, in Mode O, the condition of abandoning the online market is also related to consumers' dependence on the offline delivery service. The condition $h_o > \hat{h}_o$ equals $a < h_o^2/((6 - 4\sqrt{2})(1 - h_o))$; that is, consumers

are heavily dependent on the offline delivery service. Under this condition, the offline channel has enough advantages, and thus the retailer can abandon the online market. Second, in Mode O, when giving up the online market, the 3PL provider seizes all the profits, and the retailer's profit is 0. When h_o is large, the retailer raises the price to the possible highest level, which is independent of the delivery fee. That is, the delivery fee does not affect demand. Therefore, the 3PL provider can increase the delivery price until all the profit is obtained. This result indicates that a heavy reliance on the 3PL provider may hurt the retailer.

4.3 Mode S

In Mode S, the retailer builds its own logistics network to provide dual-channel delivery services. The retailer needs to undertake not only a unit cost ρ for each delivery but also a large fixed cost F for the construction of the logistics network. Moreover, the retailer needs to decide its additional service quality λ in addition to determining the retail price p^s . Following previous relevant literature such as Refs. [33, 34], we assume that the cost of providing additional service quality is $\lambda^2/2$. Hence, the retailer's profit function is

$$\pi_R^s = (p^s - \rho)(D_s^s + D_o^s) - \frac{\lambda^2}{2} - F. \quad (5)$$

Here, the retailer's price satisfies $0 \leq p^s \leq 1 + \lambda - h_o$, and the demand for online and offline channels is

$$D_s^s = \begin{cases} \frac{h_o}{a}, & 0 \leq p^s \leq \lambda - h_o; \\ \frac{(2 - 2p^s + 2\lambda - h_o)h_o}{2a} - \frac{(\lambda - p^s)^2}{2a}, & \lambda - h_o < p^s \leq \lambda; \\ \frac{2a}{(2 - 2p^s + 2\lambda - h_o)h_o}, & \lambda < p^s \leq 1 + \lambda - h_o; \end{cases}$$

$$D_o^s = \begin{cases} 1 - \frac{h_o}{a}, & 0 \leq p^s \leq \lambda - h_o; \\ (1 - p^s - h_o + \lambda) \left(1 - \frac{h_o}{a}\right), & \lambda - h_o < p^s \leq 1 + \lambda - h_o. \end{cases}$$

We summarize the equilibrium results of Mode S in Proposition 3.

Proposition 3. When a retailer builds its self-logistics system, the equilibrium results are shown as follows.

(i) When $0 \leq h_o \leq 1 - \rho$, $\lambda^* = 1 - h_o - \rho + \frac{h_o^2}{2a}$, $p^{s*} = 1 - h_o + \frac{h_o^2}{2a}$, and the corresponding

$$D_s^{s*} = \frac{h_o(2 - 2\rho - h_o)}{2a},$$

$$D_o^{s*} = \frac{(a - h_o)(1 - h_o - \rho)}{a},$$

$$\pi_R^{s*} = \frac{(2a(1 - h_o - \rho) + h_o^2)^2}{8a^2} - F,$$

$$CS^{s*} = \frac{3a(1 - h_o - \rho)^2 + h_o^2(3 - 2h_o - 3\rho)}{6a}.$$

(ii) When $1 - \rho < h_o \leq 1$, $\lambda^* = \frac{h_o^2}{2a}$, $p^{s*} = 1 - h_o + \frac{h_o^2}{2a}$, and

the corresponding

$$D_s^{s*} = \frac{h_o^2}{2a}, \quad D_o^{s*} = 0,$$

$$\pi_R^{s*} = \frac{h_o^4 + 4ah_o^2(1 - h_o - \rho)}{8a^2} - F, \quad CS^{s*} = \frac{h_o^3}{6a}.$$

From Proposition 3, we can find that the retail price is independent of the unit logistics cost ρ , but the logistics service quality λ has a strong connection with ρ . That is when operating a self-built logistics network, the retailer adjusts its service level rather than the price to handle the changes in logistics costs. When ρ is small, i.e., the logistics costs are low, the retailer will provide a high-level logistics service. Otherwise, the retailer's service quality will decline.

In addition, in Mode S, the condition of abandoning the online market relies on both h_o and ρ . The impact of h_o is similar to those in Modes B and O. Concerning ρ , we can infer that when ρ is high, the retailer needs to shrink certain demand to control the cost growth. Hence, the retailer reduces the service level to cut off the online market and increase the unit profit.

4.4 Sensitivity analysis

In this section, we analyze the impact of the online hassle cost h_o and consumers' dependence on the offline delivery service a on equilibrium results in different modes.

Corollary 1. The impacts of online hassle cost h_o and consumers' dependence on the offline delivery service a on the equilibrium prices and demands are as follows.

(i) The retail price p^{s*} decreases in h_o in each mode; besides, p^{o*} and p^{s*} also decrease in a .

(ii) In Mode B, the logistics price ω^{B*} decreases in h_o when $h_o \leq \sqrt{3} - 1$; in Mode O, ω^{O*} decreases in h_o and a when $h_o \leq \hat{h}_o$, and it decreases only in h_o when $h_o > \hat{h}_o$.

(iii) The offline demand D_s^{i*} increases in h_o in all modes and decreases in a in Modes O and S; the online demand D_o^{i*} decreases in h_o in all modes and increases in a in Modes O and S.

(iv) In Mode S, the logistics service quality λ first decreases and then increases in h_o but always decreases in a .

Corollary 1 shows the relationship of the equilibrium prices and demands with h_o and a . First, there is a significant negative correlation between prices with h_o and a . As the increase in h_o and a , consumers' overall hassle costs increase and the overall demand will shrink, so the retailer should reduce the price to attract consumers. The 3PL provider will also decrease the logistics price to reserve price reduction space for the retailer to maintain sufficient demand. Second, the impacts of h_o and a on demand in different channels are opposite. A higher h_o will drive some consumers to switch to the offline channel from online, and a higher a acts in the opposite way. Third, with increasing a , the importance of offline delivery declines, so the logistics service quality λ becomes lower. However, the impact of h_o on λ is more complex. When h_o is small, as h_o increases, the retailer reduces its price to attract consumers and thus can relax the service level. But when h_o is high, consumers' overall hassle costs are too high, so the retailer has to provide a better service to retain consumers as h_o increases.

Corollary 2. The impacts of the online hassle cost h_o on supply chain members' equilibrium profits and surplus are as follows.

- (i) For the retailer's profit, with the increase in h_o , π_R^{B*} first decreases, then increases, and finally decreases again; π_R^{O*} decreases in h_o when $h_o \leq \hat{h}_o$, and π_R^{S*} decreases in h_o .
- (ii) For the 3PL provider's profit, π_L^{B*} decreases in h_o when $h_o \leq \sqrt{3}-1$; π_L^{O*} first decreases, then increases, and then decreases in h_o .
- (iii) For the consumer surplus, CS^{B*} first decreases and then increases in h_o in each mode.

Taking $a = 0.8$, $\rho = 0.3$, and $F = 0.1$, we construct Fig. 2 to demonstrate the impact of h_o more clearly. As shown in Corollary 2 and Fig. 2, an increase in the online hassle cost is always detrimental to the retailer's profit when providing dual-channel logistics, but in Mode B, it may benefit the retailer. This is because the increase in the online hassle cost drives more consumers to switch to the offline channel and thus reduces the retailer's delivery expense in Mode B, but when providing dual-channel logistics, the expense cannot be saved. In contrast, the increase in the online hassle cost reduces the 3PL provider's sales in Mode B and thus hurts its profit. However, in Mode O, the 3PL provider covers the delivery in both channels and may benefit from a relatively high h_o because at this time, the retail price is relatively low, which stimulates an increase in total demand. With regard to consumer surplus, when h_o is small, consumers can enjoy a convenient shopping experience; while when h_o is large, consumers can enjoy a low price. Hence, a small h_o or a large h_o are both beneficial to consumers.

We can also observe that the retailer's profit and consumer surplus in Mode O are discontinuous at $h_o = \hat{h}_o$, while those in Modes B and S are always continuous. In Mode O, the retailer's heavy reliance on the outsourced logistics service causes the 3PL provider to achieve the dominant position in the supply chain. As h_o increases, the demand shrinks, and the 3PL provider's profit is damaged. When the demand decreases to a certain level ($h_o = \hat{h}_o$), it is lucrative for the 3PL provider to directly raise the logistics price ω to the highest level and clear the online market. But this action greatly harms the retailer and consumer group, which explains why, in Mode O, the logistics provider has a continuous profit curve, while the retailer and consumers experience a

significant loss. In contrast, the retailer is dominant in Modes B and S, so the above situation will not occur.

Corollary 3. The impacts of consumers' dependence on the offline delivery service a on supply chain members' equilibrium profits and surplus are as follows.

- (i) For the retailer's profit, π_R^{O*} decreases in a when $a \geq \frac{h_o^2}{(6-4\sqrt{2})(1-h_o)}$ (the condition equals $h_o \leq \hat{h}_o$). Meanwhile, the relationship between π_R^{S*} and a depends on ρ : If $\rho \leq 1 - h_o + \frac{h_o^2}{2}$, π_R^{S*} decreases in a ; if $1 - h_o + \frac{h_o^2}{2} < \rho \leq 1 - \frac{h_o}{2}$, π_R^{S*} first decreases and then increases in a ; if $1 - \frac{h_o}{2} < \rho \leq 1$, π_R^{S*} increases in a .
- (ii) For the 3PL provider's profit, π_L^{O*} decreases in a .
- (iii) For the consumer surplus, CS^{O*} decreases in a for both $0 \leq a < \frac{h_o^2}{(6-4\sqrt{2})(1-h_o)}$ and $a \geq \frac{h_o^2}{(6-4\sqrt{2})(1-h_o)}$, and CS^{S*} always decreases in a .

Taking $h_o = 0.3$, $\rho = 0.5$, and $F = 0.05$, Fig. 3 provides a visual description of Corollary 3. An increase in a means a decline in the importance of offline logistics and consumers' overall utility, so it will lead to a decrease in demand and hurt both the retailer and the 3PL provider in Mode O. In Mode S, the impact of a is related to the logistics costs. If the logistics costs are small, the low dependence on the offline delivery service is harmful to the retailer, which is similar to Mode O. However, if the logistics costs are large, the growth of a causes a loss of demand, which can save considerable logistics expenses, instead leading to a favorable result for the retailer. In terms of consumer surplus, with the increase in a , consumers' experience of shopping offline deteriorates, which cannot be offset by a low price, so the consumer surplus declines.

For consumers' dependence on offline delivery service a , the retailer's profit and consumer surplus under Mode O are also discontinuous at $a = \frac{h_o^2}{(6-4\sqrt{2})(1-h_o)}$. The reason is similar to that for Corollary 2. The difference is that the impacts of a and h_o on the logistics provider are opposite. As a increases, the offline delivery service is not attractive to consumers, so the 3PL provider will lower the logistics price and release the online market, which is beneficial to the

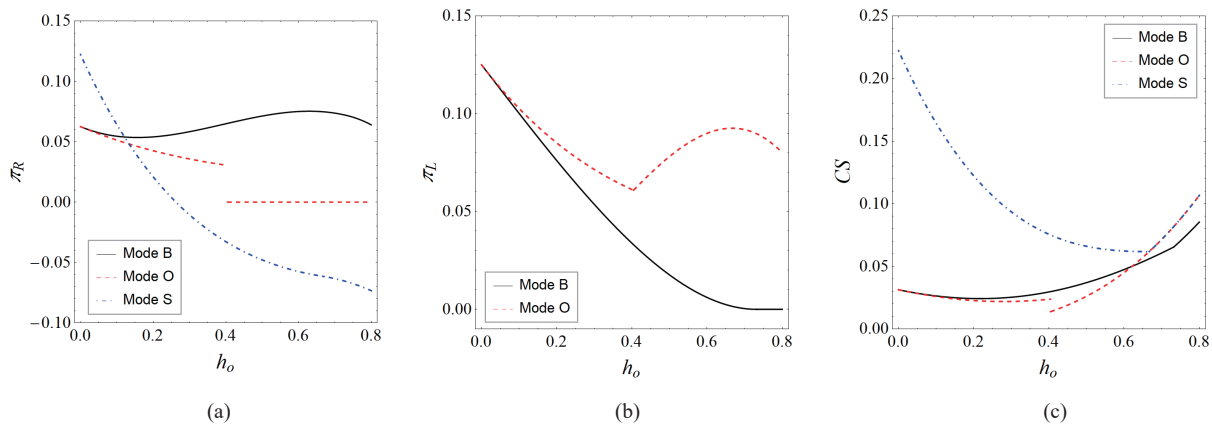


Fig. 2. The impact of the online hassle cost h_o on supply chain members' surplus.

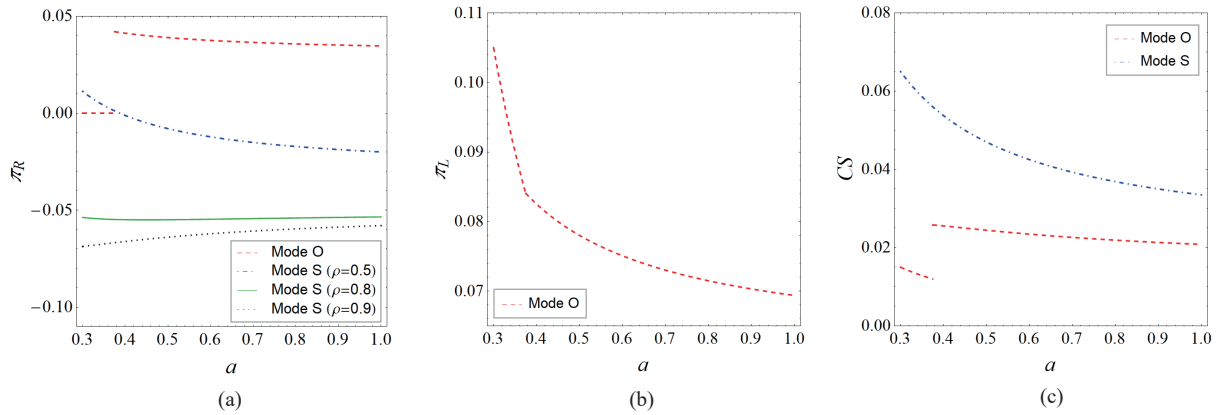


Fig. 3. The impact of consumers' dependence on the offline delivery service a on supply chain members' surplus.

retailer and consumers.

5 Result comparison and mode preference analysis

This section compares the equilibrium prices and surplus of three delivery modes, and further explores the optimal mode selection of the retailer and the preferences of other supply chain members.

5.1 The impact of delivery mode on the retail price and the 3PL provider

By comparing the optimal retail prices and the logistic service provider's profits in Propositions 1–3, we obtain Propositions 4 and 5.

Proposition 4. Given the exogenous parameters, the retailer's optimal retail prices in each mode always satisfy $p^{S*} \geq p^{O*} \geq p^{B*}$.

Proposition 4 demonstrates that compared with not providing the offline delivery service, the retailer always sets a higher retail price when providing dual-channel delivery services. Additionally, given that the self-built logistics system can afford a higher-level service, the price in Mode S will be the highest. On the one hand, a higher service level can enhance consumers' willingness to pay. On the other hand, this approach also increases the operation cost. Consequently, when providing a higher-level delivery service, the retailer always raises the retail price to obtain more profits.

Proposition 5. Given the exogenous parameters, the 3PL provider's optimal logistics prices and profits in each mode satisfy the following rules.

- (i) When $0 \leq h_o \leq \hat{h}_o$, $\omega^{O*} \leq \omega^{B*}$; when $\hat{h}_o < h_o \leq \sqrt{3}-1$, $\omega^{O*} \geq \omega^{B*}$.
- (ii) The 3PL provider's profit $\pi_L^{B*} \leq \pi_L^{O*}$ always holds.

Proposition 5 first shows the logistics price difference in Modes B and O. When $h_o \leq \hat{h}_o$, the offline and online markets in both Modes B and O operate normally. In Mode B, the 3PL provider is only responsible for online orders, and its sales are smaller than those in Mode O. Therefore, it will charge a higher delivery price to ensure enough profit. As stated in Proposition 2, when $h_o > \hat{h}_o$, the 3PL provider may raise the delivery price to extract all the supply chain profit in Mode O. Obviously, the delivery price in Mode O is higher.

We further find that compared with only delivering online

orders, the 3PL provider can always obtain higher profit when the retailer outsources orders from both channels to it. Although the unit delivery price in Mode O is lower when $h_o \leq \hat{h}_o$, the greater demand enables the 3PL provider to achieve small profit margins but high sales, thereby improving its overall profitability.

5.2 The retailer's preference for delivery mode

By comparing the equilibrium profits of the retailer in the three modes, we can obtain Proposition 6.

Proposition 6. Given the exogenous parameters, the retailer's profits in different modes satisfy the relationships shown in Table 2.

From Proposition 6, we can obtain the condition where providing dual-channel logistics services is more beneficial to the retailer than not providing offline logistics. The comparison between Modes B and O reveals that when h_o and a are low, outsourcing offline logistics is better than not providing offline logistics. Because when h_o is high, the retailer is completely constrained by the logistics firm in Mode O, and its performance is poor. Besides, if a is high, i.e., the offline delivery service is not crucial to consumers, outsourcing offline logistics cannot bring considerable sales but instead increases costs. Hence, Mode O is applicable only when h_o and a are low. The comparison between Modes B and S shows the condition where a self-built logistics network is profitable. We find that the performance of Mode S is closely related to the cost of self-logistics. When the unit delivery cost ρ is relatively low, organizing a self-built logistics network is beneficial to the retailer. In addition, a smaller a can relax the cost requirement of the dominance of Mode S because the more consumers rely on the offline delivery service, the more profitable it is to provide offline logistics, which can benefit the retailer even at a higher logistics cost.

Moreover, Proposition 6 compares the performance of the two dual-channel logistics modes. Similar to the comparison of Modes B and S, the condition where Mode S dominates Mode O also greatly depends on the logistics cost and is also regulated by a . This means that the cost is the key for a retailer to determine whether to build its own logistics network. Besides, the dependence of consumers on the offline delivery service affects their willingness to pay for high-level logistics services under Mode S, thereby affecting the retailer's profit and mode choice.

Table 2. Comparison of the retailer's profit in different modes.

Mode O and Mode B	$0 \leq h_o \leq \hat{h}_o$		$\hat{h}_o \leq h_o \leq 1$	
	$0 \leq a \leq a_1$	$\pi_R^{O*} \geq \pi_R^{B*}$	$\pi_R^{O*} \leq \pi_R^{B*}$	
	$a > a_1$	$\pi_R^{O*} \leq \pi_R^{B*}$	$\pi_R^{O*} \leq \pi_R^{B*}$	
Mode S and Mode B	$0 \leq h_o \leq \sqrt{3}-1$		$\sqrt{3}-1 < h_o \leq 1$	
	$0 \leq a \leq a_2$	$\pi_R^{S*} \geq \pi_R^{B*}$	$\pi_R^{S*} \leq \pi_R^{B*}$	$0 \leq a \leq a_3$
		$\rho < \rho_1$	$\rho > \rho_1$	
	$a > a_2$	$\pi_R^{S*} \geq \pi_R^{B*}$	$\pi_R^{S*} \leq \pi_R^{B*}$	$a > a_3$
		$\rho < \rho_2$	$\rho > \rho_2$	
Mode S and Mode O	$0 \leq h_o \leq \hat{h}_o$		$\hat{h}_o < h_o \leq 1$	
	$0 \leq a \leq a_4$	$\pi_R^{S*} \geq \pi_R^{O*}$	$\pi_R^{S*} \leq \pi_R^{O*}$	$0 \leq a \leq a_5$
		$\rho < \rho_5$	$\rho > \rho_5$	
	$a > a_4$	$\pi_R^{S*} \geq \pi_R^{O*}$	$\pi_R^{S*} \leq \pi_R^{O*}$	$a > a_5$
		$\rho < \rho_6$	$\rho > \rho_6$	

a_i and ρ_i are given in Supporting information.

Because of the complexity of the calculation, Proposition 6 can only make pairwise comparisons but cannot indicate an optimal delivery strategy. To supplement more information about Proposition 6, we use numerical analysis to investigate the retailer's choice of the three modes. Since Proposition 6 has verified the obvious negative correlation between the performance of Mode S and the logistics costs, our numerical analysis mainly focuses on the impact of h_o and a . Fixing the value of $F = 0.05$, we choose different values of ρ , change the values of h_o and a in $[0, 1]$, and compare the corresponding profit π_R^* . The results are shown in Fig. 4, which illustrates the retailer's final choice of delivery modes.

Fig. 4 demonstrates the importance of the cost of self-built logistics again. We can observe that when ρ is small, Mode S dominates the other two modes to a great extent. But when ρ is large, Mode S will perform the worst. Meanwhile, we unexpectedly discover that Mode B is optimal for the retailer when the online hassle costs h_o is relatively high. This is an amazing finding. A high h_o means that consumers prefer the offline channel, but Mode B, which has the worst offline delivery service, performs best under this condition. Analyzing this result, we can obtain that when h_o is high, the retailer will reduce its price, and the profit margin will decrease. In

addition, most consumers purchase offline, and thus the retailer needs to pay a large logistics fee when choosing Modes O or S. In contrast, although not providing offline logistics may result in demand loss, this loss is not significant when the price is low. Moreover, not providing offline logistics can save considerable logistics costs, which is enough to offset the demand loss. Therefore, Mode B is optimal when h_o is high.

When h_o is relatively low, Modes S and O can perform better. The main difference is that the dominance of Mode O depends more on a relatively low a , while Mode S is not very sensitive to a . This is because the advantage of Mode O lies in the offline channel, so consumers' dependence on the offline delivery service is crucial to Mode O. However, Mode S can simultaneously improve the consumer utility in both channels and thus the impact from the single offline channel is not too significant.

From the above discussion, we can summarize the suggestions for home furnishing retailers. If consumers heavily rely on the offline delivery, for example, if the car ownership rate is low or the store location is relatively remote, the retailer is recommended to outsource its dual-channel logistics. If the online channel is convenient and the logistics costs such as

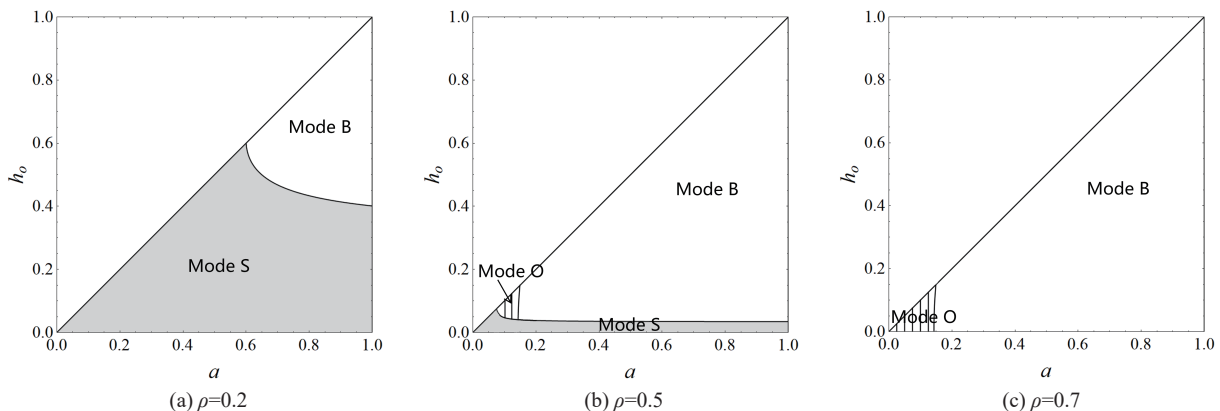


Fig. 4. The optimal delivery strategy of the retailer.

labor costs and fuel costs are low, the retailer should build its own logistics network for order delivery. If the online channel is not convenient for consumers, not providing offline delivery is the best choice. In addition, for retailers that have already provided dual-channel delivery services, trying to decrease the online hassle costs can boost their profit. This conclusion can explain the business practice in China. Online shopping is very convenient in China. Many factors, such as the development of electrical payments, big data recommendation systems, and live-streaming displays, have greatly reduced the cost of online shopping. However, because of the relatively low car ownership, it is not convenient for consumers to pick up offline. In addition, owing to China's expansive land area, logistics networks are required to be large-scale and thus generate considerable operating costs. Therefore, at present, most domestic home furnishing retailers in China outsource offline logistics to 3PL providers, while the self-built logistics development of the home furnishing industry remains in its infancy.

5.3 Consumer surplus under different delivery modes

In this section, we compare the consumer surplus and obtain Proposition 7.

Proposition 7. Given the exogenous parameters, the consumer surplus under different modes satisfies the following relationship (ρ_i are given in the Supporting information).

- (i) When $\sqrt{3}-1 < h_o \leq 1$, $CS^{B*} \leq CS^{O*} \leq CS^{S*}$ always holds.
- (ii) When $0 \leq h_o \leq \hat{h}_o$, if $a \leq a_6$, we have $CS^{O*} \geq CS^{B*}$; otherwise, $CS^{O*} \leq CS^{B*}$. When $\hat{h}_o < h_o \leq \sqrt{3}-1$, if $a \leq a_7$, we have $CS^{O*} \geq CS^{B*}$; otherwise, $CS^{O*} \leq CS^{B*}$.
- (iii) When $0 \leq h_o \leq \sqrt{3}-1$, if $a \leq a_7$, we have $CS^{S*} \geq CS^{B*}$; if $a > a_7$, we have $CS^{S*} \geq CS^{B*}$ when $\rho \leq \rho_9$ and $CS^{S*} \leq CS^{B*}$ when $\rho \geq \rho_9$.
- (iv) When $0 \leq h_o \leq \hat{h}_o$, if $a \leq a_8$, we have $CS^{S*} \geq CS^{O*}$; if $a > a_8$, we have $CS^{S*} \geq CS^{O*}$ when $\rho \leq \rho_{10}$ and $CS^{S*} \leq CS^{O*}$ when $\rho \geq \rho_{10}$. When $\hat{h}_o < h_o \leq \sqrt{3}-1$, $CS^{S*} \geq CS^{O*}$ always holds.

Proposition 7 shows the condition where providing dual-channel logistics can benefit the consumer group. We find that providing dual-channel delivery services, whether outsourced or self-built, is beneficial to the consumer group when h_o is very large or a is small. When h_o is very large, the

online channel is too inconvenient for consumers, and almost all the demand is concentrated in the offline channel; thus, the offline delivery service can be very useful. Meanwhile, when a is small, consumers are heavily dependent on the offline delivery service, and thereby providing offline delivery can significantly improve consumers' experience. In addition, the impact of Mode S on consumer surplus is also related to the cost ρ . Even when h_o is small and a is high, as long as the cost is low enough, the retailer's logistics quality will be high under Mode S, and thus consumers can benefit from it.

Comparing the consumer surplus in Modes O and S, we can discover that for the consumer group, in most cases, Mode O never surpasses Mode S. That is, Mode S with higher service quality is more likely to benefit consumers than Mode O, although its price is higher. Only a relatively small h_o , a relatively large a , together with a large ρ can make Mode S inferior to Mode O. Under this condition, consumers do not rely heavily on offline delivery, and the service quality in Mode S is low, so their willingness to pay for the high price in Mode S is not high. Besides, the price in Mode O is not high. Therefore, Mode O has a higher performance-price ratio for consumers.

Similar to Fig. 4, to supplement more information and show Proposition 7 more clearly, we draw Fig. 5 to illustrate the consumer group's preference for delivery modes. It can be observed from Fig. 5 that the increase in cost ρ also exerts a significantly negative impact on consumers' preference for Mode S. As ρ increases, the retailer's logistics service level decreases, yet the retail price remains unchanged, thereby resulting in a decline in consumer utility. With regard to h_o and a , we can find that when h_o falls outside a middle range (i.e., either low or high), or when a is relatively small, providing dual-channel logistics is better for the consumer group. Specifically, when h_o is high and a is relatively low, Modes S and O are equally preferred by consumers. In this case, most demand is concentrated in the offline channel, and consumers are dependent on the offline delivery service, so providing offline logistics is naturally more popular. Meanwhile, the lack of online demand weakens the advantages of Mode S in enhancing the utility of online consumers, leading to the same performance of Mode O and Mode S. On the contrary, when h_o is low, the online channel can attract more consumers, and as the only delivery mode that can enhance online consumers'

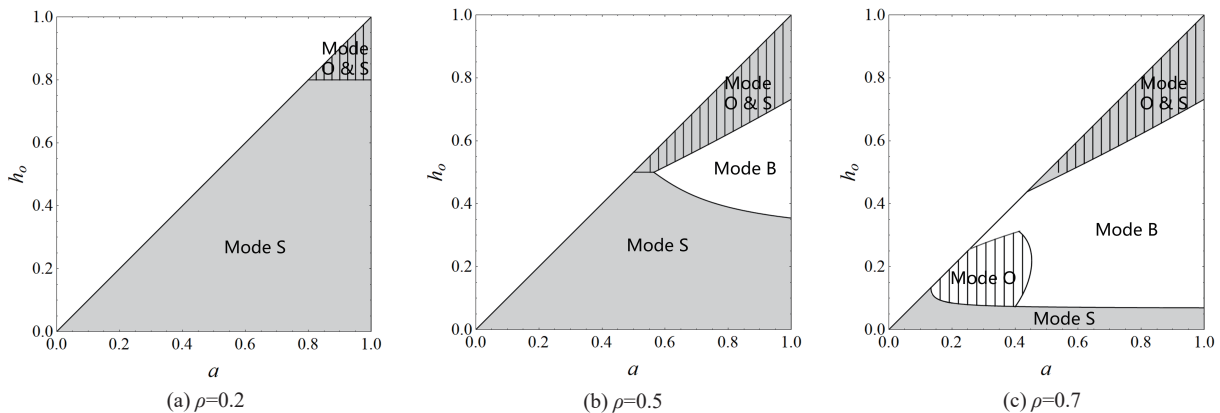


Fig. 5. The consumer group's preference for delivery modes.

utility, Mode S is the most beneficial to consumers. Moreover, when ρ is high and a is relatively low, consumers prefer Mode O if h_o is not very low. In this case, consumers are dependent on offline delivery, but the service level of self-built logistics is low and the price is high, so Mode O is better for consumers.

Compared to the retailer, consumers prefer Modes S and O more than the retailer but prefer Mode B less. Consumers do not need to consider logistics costs; therefore, delivery modes with a higher service level are more likely to be favored by them. Only when h_o is moderate and a is relatively large do consumers prefer Mode B. Under this condition, the distribution of the demand between the two channels is balanced, so the advantages of the offline delivery service and high-quality online logistics in Mode S are relatively less obvious. Moreover, consumers place little valuation on offline delivery services, and thus the provision of dual-channel logistics fails to effectively boost consumer utility.

Considering the supply members' surplus comprehensively, we find that when the online hassle cost is relatively low, the retailer's and consumers' preferences may reach an agreement; in contrast, when the online hassle cost is high, their preferences are always contradictory. Taking the 3PL provider who always prefers Mode O into account, the tripartite win-win outcome can only be achieved when ρ is high and a is low.

6 Conclusions

Nowadays, China's home furnishing industry is developing from single-channel retailing to dual-channel layout with deep integration of online and offline channels. The personalized demand of consumers and the unique inherent attributes of home furnishing products make consumers attach great importance to the dual-channel logistics, and thus retailers are paying more attention to the delivery service of home furnishing products. To address the dual-channel home furnishing logistics issue and improve consumer experience, home furnishing retailers have different methods for order delivery. Based on the business practice, this paper innovatively constructs a game-theoretic model between a dual-channel home furnishing retailer and a 3PL provider, explores the optimal choice of delivery modes for the retailer, and discusses the influence of the delivery modes on the price and supply chain member surplus. Our work has the following findings. First, when the online hassle cost is high or the self-built logistics costs are high, the retailer will adjust its retail price or logistics service level to strategically give up the online market. Second, the provision of higher-level delivery services leads to higher retail prices, though this does not necessarily increase the retailer's profit. The retailer's optimal delivery mode is affected by consumers' perceptions of the online and offline shopping experiences, as well as the logistics costs. Mode S dominates when the online hassle cost or unit logistics cost is low, while Mode B performs better when the online hassle cost is high. The dominant condition of Mode O requires consumers' heavy reliance on offline delivery. Third, outsourcing the dual-channel delivery always benefits the 3PL provider, but the dual-channel delivery service does not

necessarily benefit the consumer group. Only when the cost of self-built logistics is high and consumers rely heavily on offline delivery can outsourcing dual-channel delivery achieve a triple-win outcome for all supply chain members.

This research is subject to several limitations. First, this paper ignores the service level decision of the 3PL provider. In fact, the service level of outsourced logistics varies among different logistics providers. In Modes B and O, the service level of logistics also affects the utility of consumers and subsequently affects the demand. Second, this paper examines only one retailer without considering the market competition. Nevertheless, interfirm competition drives retailers to upgrade service quality, which in turn alters their pricing and delivery strategies. Finally, this paper only considers the game in a single period. In reality, the self-built logistics system often has little short-term returns yet generates long-term benefits for retailers. Future research may use dynamic methods to model the long-term operations.

Supporting information

The supporting information for this article can be found online at <http://doi.org/10.52396/JUSTC-2023-0168>. It includes the proofs of all the propositions and corollaries.

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Conflict of interest

The authors declare that they have no conflict of interest.

Biographies

Yuwen Da is currently a Lecturer at Jiangsu Police Institute. She received her Ph.D. degree from the University of Science and Technology of China in 2025. Her research mainly focuses on supply chain risk management and platform-based supply chain management.

Jiashu Cui is currently an Assistant Lecturer at Shenyang Jianzhu University. She received her Master's degree from the University of Science and Technology of China in 2024. Her research mainly focuses on logistics and supply chain management.

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