JUSTC Article
http://justc.ustc.edu.cn Received: December 31, 2021; Accepted: May 05, 2022

Delivery mode selection of home furnishing e-retailer based on a combination of logistics delivery and installation service

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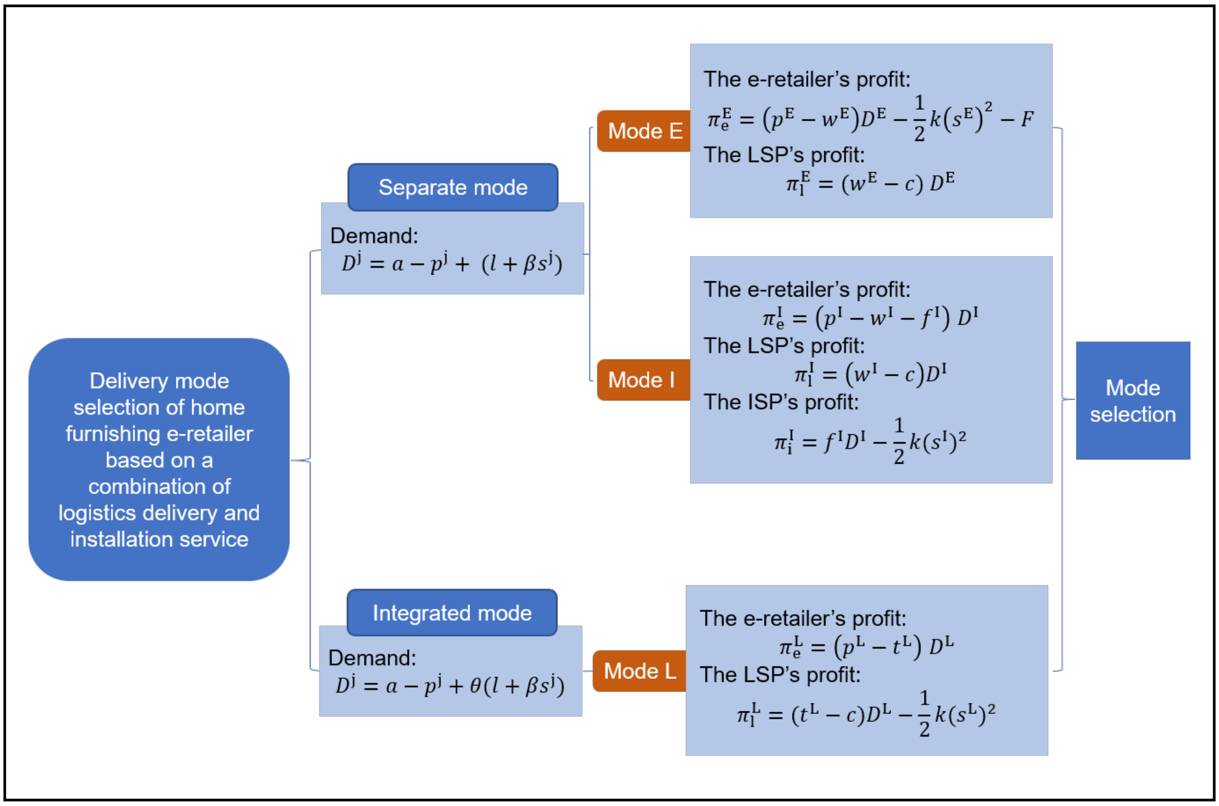
Graphical abstract



The overall framework of our delivery selection model.

Public summary

- For the e-retailer, when the installation service's cost performance (τ) is relatively high, the e-retailer will choose Mode E if and only if the self-built fixed cost (F) is relatively low, otherwise, the e-retailer will choose Mode L.
- The e-retailer and the LSP reach a win-win situation from the Mode L when the installation service's cost performance (τ) is relatively low. The e-retailer and the LSP reach a "win-win" situation from the Mode E when the installation service's cost performance (τ) is relatively high and the self-built fixed cost (F) is low.
- Compared with the Mode L, the Mode S cannot be a better choice for the e-retailer if the self-built fixed (F) cost is too high.

Citation: Chen Y L, Wang M M. Delivery mode selection of home furnishing e-retailer based on a combination of logistics delivery and installation service. *JUSTC*, **2023**, 53(1): 5. DOI: 10.52396/JUSTC-2021-0282

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Cite This: *JUSTC*, **2023**, 53(1): 5 (12pp) Read Online Supporting Information

Abstract: With the increasing demand for online home-furnishing products, product delivery services, especially installation services, have become increasingly regarded as bottlenecks and key factors for success. Meanwhile, customers have different preferences for a combination of delivery modes because of separated or synchronized logistics delivery from installation services. It is essential for online home-furnishing e-retailers to self-build or outsource installation services. This study investigates the optimal delivery mode selection of home-furnishing e-retailers in a home-furnishing supply chain consisting of a home-furnishing e-retailer, a third-party installation service provider (ISP), and a third-party logistics service provider (LSP). Specifically, we explore three alternative modes: (ⅰ) The home-furnishing e-retailer undertakes the installation service (Mode E); (ⅱ) the ISP undertakes the installation service (Mode I); (ⅲ) the LSP undertakes the installation service (Mode L). The results reveal that the self-build mode does not always generate the highest installation service level, and the integrated delivery mode may generate the highest installation service level when the cost performance of the installation service is relatively low. Moreover, optimal delivery mode selection depends on the installation service's cost performance. When the installation service's cost performance is relatively low, the e-retailer and the LSP reach a "win-win" situation from the integrated delivery mode. When the installation service's cost performance is relatively high and the self-build fixed cost is low, the e-retailer and the LSP reach a win-win situation from the self-build mode. Interestingly, compared with the outsourced integrated service mode, the self-build integrated service mode is not a better choice for the e-retailer if the self-build fixed cost is too high. Our study contributes to the growing literature on home furnishing and guides the implementation of delivery strategies for large-product online retailers.

Keywords: home-furnishing e-retailer; delivery mode; installation service; customer preference

CLC number: F252 **Document code:** A

1 Introduction

In recent years, the consumption habits of home appliance and furnishings customers have gradually changed from offline to online, and there is an increasing market demand for home appliances, furniture, building materials, sanitary ware, and other large home-furnishing products. On April 23, 2021, the 2020 Home After-sales Service Industry Report showed that the online penetration rate of the home-furnishings market exceeded 10%, and the market size reached ¥626 billion, which is representative of an upward trend over the past five years①. In 2020, retail e-commerce revenue from furniture and homeware sales amounted to $52.6 billion and is projected to increase to over $61.2 billion in 2025②. As the furniture industry shifts from offline to online, product delivery, the final stage of an e-commerce transaction, has become a core factor that significantly affects customer purchase experience[1].

Home-furnishing product delivery includes logistics delivery and installation services, with installation being a particularly value-added service dedicated to the home e-commerce industry. A negative delivery outcome reduces overall customer satisfaction and can damage future customer relationships with a given e-retailer[2]. The delivery process of home furnishing products involves product logistics delivery followed by installation. Product logistics usually rely on professional logistics service providers (LSPs), but the installation service can be self-build, outsourced to installation service providers (ISPs), or outsourced to third-party LSPs[3]. For example, large home-furnishing enterprises, such as QuanU, Haier home applications, and NipponPaint, mainly rely on a self-build installation network, which can control the installation service and provide professional installation due to good knowledge of the product features. However, self-building installation systems incur high fixed costs. Most home-furnishing e-retailers on JD.com or Tmall.com outsource installation services to third-party ISPs, such as Wanshifu.com, lbdj.com, or local installation teams, which can focus on their core competencies.

These traditional delivery services separate logistics deliv-

① http://finance.china.com.cn/roll/20210426/5559094.shtml.
② https://www.statista.com/topics/5171/furniture-e-commerce-in-the-united-states/.

eries from installation services. The separated modes bring some problems for customers, such as wasted time, untimely installation, and higher costs, resulting in poor customer experience. However, when the e-retailer outsources the installation service to a third-party LSP, the logistics delivery and installation services are integrated. Customer experience is better than separated logistics delivery and installation services. Large home-furnishing businesses have captured the benefits of integration. For example, GOME's "integrated delivery and installation" service solves the problem of the simultaneous delivery of home-furnishing products for customers①. Suning Logistics takes the lead in integrating logistics delivery and installation services from customers' perspective. Judging from usage in Neijiang City, the "integrated delivery and installation" of color TVs in the area reached 5000 units in 2017 and delivery sales accounted for 67.8% of local sales. More than half of customers would choose Suning's "integrated delivery and installation" service②. The logistics director of home furnishings said that cooperation with integrated LSPs can produce the effect of "1+1>2" ③. Under the integrated delivery mode, seamless product logistics delivery and installation services can improve the expected delivery efficiency and increase customers' perceived value.

Based on the observation of the home-furnishing e-commerce industry, our study innovatively introduces different installation service modes considering customers' different preferences for service modes resulting from different ISPs. This study aims to explore the optimal combination mode of home-furnishing e-retailers. More specifically, we address the following questions:

(ⅰ) Which mode brings the highest installation service level and the lowest retail price?

(ⅱ) What is the profitability of supply chain members under different modes?

(ⅲ) How does the mode selection of home-furnishing e-retailers differ in terms of installation service's cost performance and self-build fixed cost?

To answer the above questions, we develop a three-layer home-furnishing supply chain consisting of a home-furnishing e-retailer, a third-party LSP, and an ISP. We assume that the home-furnishing e-retailer sells a home-furnishing product online and provides customers with delivery, including logistics delivery and installation services. Logistics delivery provided by the LSP and installation services can be undertaken by different members of the supply chain. Specifically, we mainly explore three mode selections: (ⅰ) In the home-furnishing e-retailer mode (mode E), the e-retailer sells the product and undertakes the installation service. (ⅱ) In ISP mode (mode I), the e-retailer sells the product and outsources the installation service to the ISP. (ⅲ) In the LSP mode (mode L), the e-retailer sells the product and outsources the installation service to the LSP. Our research reveals that the self-build mode does not always generate the lowest retail prices. Furthermore, intuitively, to grow demand, the home-furnishing e-retailer must provide a better installation service than the third party; however, we find that the LSP is willing to provide a higher level of installation service. Moreover, the installation service level is the main factor that affects the mode selection of home-furnishing e-retailers; that is, if the installation service's cost performance is relatively high and the self-build fixed cost is relatively low, the home-furnishing e-retailer will choose to provide the installation service on their own. For the LSP, providing integrated logistics delivery and installation services are the optimal choice when the installation service's cost performance is relatively low. Finally, both mode E and mode L can enable home-furnishing e-retailers and LSPs to achieve win-win situations under certain conditions.

In this extension, we consider an e-retailer with a self-supporting logistics service system. We find that the e-retailer has more incentives for the installation service. Interestingly, if the self-build fixed cost is too high, we find that the self-build integrated logistics delivery and installation service mode cannot be a better choice for the e-retailer than the outsourced integrated logistics delivery and installation service mode.

The main contributions of this study are as follows: First, it proposes simultaneous logistics and installation service delivery problems with customer preferences. Second, we present a game analysis model for the problem, including the coexistence of multiple service providers due to two-stage services. Moreover, we provide not only the optimal mode selection from the perspective of home-furnishing e-retailers, but also the win-win conditions of the e-retailer and LSP. Finally, we present a possible alternative, whereby some e-retailers with self-supporting logistics systems, such as JD.com and Amazon, can outsource the services to a LSP who provides an integrated delivery service rather than self-building the installation if the self-build fixed cost is too high. Our findings provide an example for online e-commerce enterprises to provide after-sales and value-added services.

The remainder of this paper is organized as follows. Section 2 presents the literature review. The problem characteristics and notations are presented in Section 3. The equilibrium results for the different delivery modes are presented in Section 4. Section 5 presents the main insights of the mode selection. In Section 6, we extend the base model. Finally, Section 7 draws conclusions and suggests future research directions.

2 Literature review

Four streams of research are closely related to our work. The first stream is research on furniture delivery; the second is related to service outsourcing in operations management (OM); the third relates to service supply chain management and customer preferences. We review some related articles, compare our study, and highlight the main differences.

Our study is closely related to the furniture delivery industry. Some studies have focused on the transportation industry of furniture retailers. Audy and D'Amours[4] identified significant potential benefits in transportation operation coordination through collaborative planning. Audy et al.[5]

① https://news.tom.com/201907/4621476186.html.
② http://www.chinawuliu.com.cn/zixun/201710/17/325463.shtml.
③https://xw.qq.com/cmsid/20200917A0KBLN00?f=newdc.

DOI: 10.52396/JUSTC-2021-0282
JUSTC, 2023, 53(1): 5

demonstrated that collaboration in transportation could provide cost savings and reduce delivery time. Yu et al.[6] reviewed logistics models in e-commerce logistics and e-commerce logistics in supply chain management implementation. Marino et al.[7] used the furniture industry as an example to evaluate the effect of delivery time on demand and empirically identify marketing-mix variables that influence retailers' strategies. Some scholars have focused on home delivery logistics in e-commerce, known as "last-mile delivery". Goyal et al.[8] and Luo et al.[9] provided solutions to logistic networks for home delivery or logistics systems for furniture and large appliances in urban settings from the perspective of the Physical Internet. Coelho et al.[10] and Li et al.[11] modeled and solved a vehicle routing problem with time windows in the furniture industry delivery. In fact, installation service as a new competitive value-added service is also the focus of research in the home-furnishing delivery process. Bae and Moon[12] considered a situation where delivery and installation service vehicles were operated separately. Recently, Ali et al.[3] dealt with a delivery problem that considered separating or synchronizing delivery from installation and solving the delivery and installation routing problem, which is similar to our study. All the above studies neither consider the characteristics of a home-furnishing industry that is currently a disconnected supply chain nor consider the operation of a home-furnishing e-retailer from the perspective of supply chain management. We establish an analytical game model to solve the problem of choosing an ISP, which results in the optimal delivery mode combination of logistics delivery and installation services for home-furnishing e-retailers.

The second strand of literature focuses on the selection of product delivery modes. Some studies have focused on the selection of the product delivery mode. Chang et al.[13] examined online retailers' selection of shipping policies by analyzing customer and social welfare. Considering scheduling problems, Wang and Lee[14] studied mode choice in two product-delivery modes. Choi[15] derived an optimal delivery mode selection and inventory ordering policy using an internet-based elastic logistics platform. Stecke and Zhao[16] confirmed that customers may prefer a commit-to-delivery business mode under two modes (i.e., commit-to-delivery and commit-to-ship) used in a make-to-order industry, and Li et al. [17] studied an integrated production and delivery problem in the commit-to-delivery mode. Most studies have focused on the selection of the last-mile delivery mode. Punakivi et al.[18] studied the two main modes of unattended delivery (i.e., the reception box concept and the delivery box) and assessed which worked better by simulating cost savings. Wang et al.[19] explored the cost competitiveness of three last-mile delivery modes and demonstrated how to choose different modes. Tiwapat et al.[20] investigated five modes of last-mile delivery by depicting and comparing efficiencies from the perspective of stakeholders. Devari et al.[21] demonstrated crowdsourcing of last mile delivery by exploiting the social network of customers. Others have focused on last mile routing selection[3,12]. Some studies have focused on logistics service mode selection. Lou et al.[22] explored logistics service choices of self-building or outsourcing in a retailer-led supply chain. Wang et al.[23] studied logistics mode selection in three cross-border logistics models, considering product returns. Büyüközkan et al.[24] proposed a multi-criterion decision-making approach to select strategic alliance partners in the logistics value chain. Ozcan and Ahiskali[25] focused on the selection of five third-party service providers for a foreign trade company, according to their performance. Göl and Çatay[26] selected a global LSP using an analytic hierarchy process for multicriteria decision-making. Punakivi and Hinkka[27] analyzed the selection criteria of delivery services and considered which mode of logistics service industrial sectors use and why. Our research differs from these studies by exploring the e-retailer's combination mode selection of the logistics and installation service (i.e., separated and integrated modes) considering customers' delivery service preference, which has not been studied in the literature. We are interested in the optimal combination of logistics and installation service strategy by choosing different ISPs.

Our study is also related to the literature on service outsourcing. Some studies focus on whether to outsource or not[22, 28] and the comparison between self-build and outsourced logistics models[6]. In contrast to Lou et al.[22] and Yu et al.[6], we consider different outsourcing modes because of customers' preferences for the delivery mode. In terms of outsourcing modes, some studies focus mainly on the equilibrium strategy of outsourcing modes. Bolandifar et al.[29] analyzed delegation and control outsourcing modes in a supply chain. Both Kayış et al.[30] and Wang et al.[31] considered two outsourcing modes of delegation and control and then presented conditions in which one is more profitable than the other. A variety of studies focus on other industry-specific service outsourcing, such as a fresh agri-product supply chain[32], durable products[33], and remanufactured products[34]. As noted in the above studies, outsourcing payments differ under different outsourcing modes. Considering the characteristics of the industry, our study also emphasizes who undertakes installation services under different service outsourcing mode selections, in that different ISPs result in different delivery preferences.

Another strand of the literature concerns service supply chain management. Several studies have focused on coordination strategies. Liu et al.[35] studied coordination strategies using a logistics service supply chain during demand disruption. Song and He[36] designed different contract mechanisms to achieve the coordination of a three-layer fresh agricultural product supply chain in centralized and decentralized channels. Some studies focus on marketing strategies. Hu et al.[37] characterized the channel integration strategy for an online retailer by considering three power structures. Zheng et al.[38] considered whether to introduce a third-party seller who sells a substitutable product to investigate the downstream retailer's optimal strategy. The above studies only explored supply chain management from a single service or marketing strategy. However, the available findings reveal a link between customers' perception of the online experience and their experience following parcel delivery, which affects customer demand in supply chain management. Cognitive dissonance due to delivery delays impacts customers' perceptions of the online shopping experience[39]. Vakulenko et al.[2] showed that a well-designed online purchase experience must

DOI: 10.52396/JUSTC-2021-0282
JUSTC, **2023**, 53(1): 5

focus on customer delivery requirements. This new perspective prescribes that firms develop and market their goods and services as a sequence of purchasing and consuming events[40]. Qin et al.[41] examined the optimal combination of selling mode and logistics service strategy when an online platform serves as a reseller or a marketplace provider in an e-commerce market, which is similar to our study. However, considering that the home-furnishing industry characteristics of overall services included a two-stage service, our research not only considers the impact of service combination strategies on marketing, but also considers customers' preference for service mode due to the flexibility in separation or synchronization of the service delivery process.

In the home-furnishing e-commerce industry, many have already addressed the planning for product delivery from different perspectives; however, to the best of our knowledge, no one has ever studied the optimal combination mode selection in home-furnishing supply chain management due to the different ISPs. Our study contributes to the furniture industry delivery literature by establishing an analytical model from the perspective of operation and solving the optimal delivery mode selection based on the characteristics of the home-furnishing industry. Moreover, although there are many relevant studies on the mode selection problem, most address the problem by ignoring one or the other important characteristics. Customers' preferences for integrated services in a two-stage service will affect customers' demands, especially in the home-furnishing industry. Our study also contributes to the literature on service outsourcing and delivery mode selection in OM by identifying two service outsourcing modes that differ from one self-build mode and considering customers' preferences for the delivery mode.

3 Model framework

We consider a home-furnishing supply chain that consists of one home-furnishing e-retailer that provides the product, one third-party LSP, one ISP, and a continuum of customers. The e-retailer determines the retail price p and releases logistics and installation information details. Customers browse products online, ask the customer service for a delivery mode that separates or synchronizes delivery from installation, and then determine the order. During product delivery, the e-retailer delivers the product with a fixed logistics service level l by the LSP and an installation service level s by different ISPs to the customers.

Considering the e-retailer's installation mode selection, there are three possible supply chain service combination modes, as illustrated in Fig. 1. In the Mode E, the LSP first offers the logistics service and determines the logistics service price w^E, then the e-retailer determines the installation service level s^E and retail price p^E. In the Mode I, the LSP first offers the logistics service and determines the logistics service price w^I, Simultaneously, the ISP determines the installation service level s^I and the installation service price f^I. Finally, the e-retailer determines retail price p^I. In the Mode L, the LSP undertakes the integrated logistics delivery and installation service, determines the installation service level s^L and the total delivery service price t^L, then the e-retailer determines the retail price p^L.

The market demand for the product is sensitive to retail price (p^j), logistics service level (l), and installation service level (s^j), where subscript j represents the different delivery modes (j = E, I, L). Specifically, market demand decreases with the retail price and increases with the logistics service and installation service levels. A similar demand function is common in the marketing and operations literature[42,43]. Moreover, considering customers' preferences, Jain and Bala[44] set parameter θ to denote customers' willingness-to-pay for product quality, which ultimately affects demand. Moreover, Yu and Xiao[45] set a parameter h to denote the ability of a cold-chain service to keep products fresh, which affects the base sensitivity of customers to the freshness level, and the combination of the services also affects the market demand. Similarly, we introduce the preference parameter θ into the demand function to describe customer sensitivity to the combination mode of market demand. The specific functional form is given by

$$D^j = a - p^j + \theta^j(l + \beta s^j), \tag{1}$$

where a represents the market potential and θ^j denotes customers' sensitivity of the market demand to the combination mode, reflecting their preference for an integrated delivery service. When separating logistics delivery from installation, $\theta^j = 1$; when synchronizing logistics delivery and installation, $\theta^j = \theta > 1$. In practice, not all customers have a strong desire for synchronized delivery, and some customers pursue professional installation department requirements. For example, in

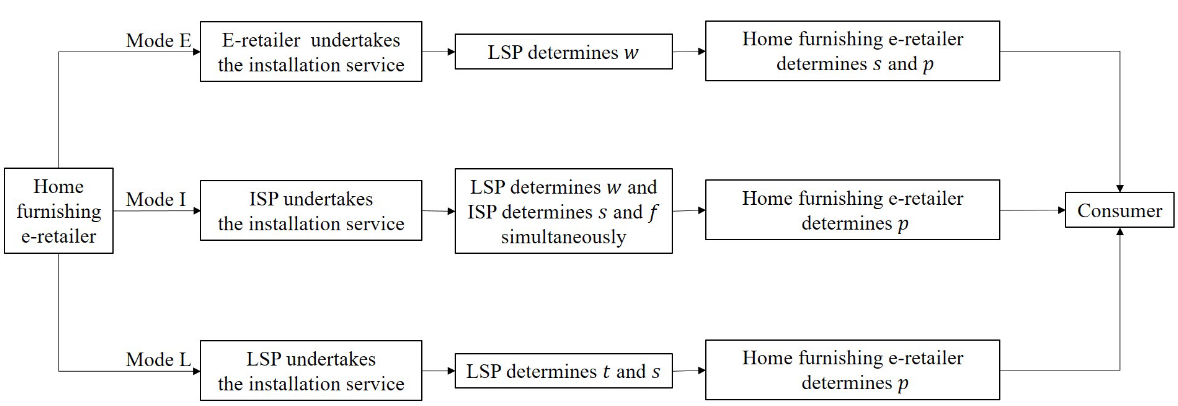

Fig. 1. The sequence of events.

DOI: 10.52396/JUSTC-2021-0282
JUSTC, **2023**, 53(1): 5

2020, Deppon Express upgraded its services in the field of furniture and home-furnishing delivery and launched a "double-decker delivery network" based on customer habits. Based on the original "synchronized logistics delivery and installation" service, a "delivery and installation separation" service is provided; that is, the courier is responsible for door-to-door delivery and the installer is responsible for door-to-door installation[46]①. To be consistent with the fact that, in business practice, delivery service preference is not very high, we assume that $\theta < \sqrt{2}$ in the main model.

Moreover, we assume that the e-retailer, LSP, and ISP have sufficient capital and the capability to offer installation services to customers. The cost of providing installation services with service level s is $\frac{1}{2}ks^2$, where the quadratic form suggests diminishing returns on such expenditures, and k is referred to as the firm's installation service cost factor[42]. In line with the studies of Liu et al.[47] and Zhang et al.[48], we assume that the e-retailer, LSP, and ISP have identical installation service cost factors (i.e., $k^{\mathrm{E}} = k^{\mathrm{L}} = k^{\mathrm{I}} = k$) and that $k > \frac{\beta^2}{2}$ to ensure that all variables are positive. Furthermore, because of the need for an additional fixed labor cost to establish and maintain the installation team, we assume that an e-retailer has a self-build fixed cost F when establishing an installation service system, except for the service cost $\frac{1}{2}ks^2$. We assume that the LSP has a unit fixed logistics cost c with a fixed logistics level l. Finally, without loss of generality, we also assume that the marginal cost of supplying the product is normalized to zero. This assumption has been widely adopted in the literature[49, 50]②. The key notations used in our model are summarized in Table 1.

4 Model analysis

In this section, by assuming that both the LSP and the ISP are determined ex-ante, we analyze the equilibrium for modes E, I, and L, respectively.

4.1 Mode E

In mode E, the LSP provides the logistics service and the e-retailer undertakes the installation service. The profits for the e-retailer and the LSP are as follows:

$$\pi_{\mathrm{e}}^{\mathrm{E}} = (p^{\mathrm{E}} - w^{\mathrm{E}})(a - p^{\mathrm{E}} + (l + \beta s^{\mathrm{E}})) - \frac{1}{2}k(s^{\mathrm{E}})^2 - F, \tag{2}$$

$$\pi_{\mathrm{l}}^{\mathrm{E}} = (w^{\mathrm{E}} - c)(a - p^{\mathrm{E}} + (l + \beta s^{\mathrm{E}})). \tag{3}$$

We solve this game using backward induction and obtain the equilibrium results.

Proposition 4.1. In mode E, the equilibrium results are as follows:

$$p^{\mathrm{E}} = \frac{k(3a + c + 3l) - (a + c + l)\beta^2}{2(2k - \beta^2)},\ w^{\mathrm{E}} = \frac{(a + c + l)}{2},$$

$$s^{\mathrm{E}} = \frac{(a - c + l)\beta}{2(2k - \beta^2)},\ D^{\mathrm{E}} = \frac{k(a - c + l)}{2(2k - \beta^2)},$$

$$\pi_{\mathrm{e}}^{\mathrm{E}} = \frac{k((a - c + l)^2 - 16F) + 8F\beta^2}{8(2k - \beta^2)}, \pi_{\mathrm{l}}^{\mathrm{E}} = \frac{k(a - c + l)^2}{8(2k - \beta^2)}.$$

As the market potential a and logistics service level l increase, the equilibrium results also increase. However, as the unit fixed logistics cost c increases, the equilibrium logistics service price w^{E} increases, the logistics service level s^{E}, demand D^{E}, and firms' profits $\pi_{\mathrm{e}}^{\mathrm{E}}$, $\pi_{\mathrm{l}}^{\mathrm{E}}$ decrease.

To ensure positive profit for the e-retailer in mode E, we assume $F < \bar{F} = \frac{k(a - c + l)^2}{8(2k - \beta^2)}$.

Corollary 4.1. The impacts of installation service cost factor (k) and installation service level sensitivity (β) on equilibrium results under Mode E are as follows:

(ⅰ) w^{E} is independent of k and β.

(ⅱ) p^{E}, s^{E}, D^{E}, $\pi_{\mathrm{e}}^{\mathrm{E}}$, and $\pi_{\mathrm{l}}^{\mathrm{E}}$ always decrease with k, but increase with β.

Corollary 4.1(ⅰ) shows that logistics service price w^{E} is not affected by k or β. In Mode E, the LSP's profit, considering only the size of the market, combines its own fixed

Table 1. Notation of the model.

Parameters	
a	Market potential for the product
l	Unit fixed logistics service level, $l > 0$
β	Sensitivity of the market demand to the installation service level, $\beta > 0$
θ	Customers' sensitivity of the market demand to the combination mode, reflecting their preference for integrated delivery service, $1 < \theta < \sqrt{2}$.
k	Firm's installation service cost factor
c	LSP's unit fixed logistics cost
F	E-retailer's self-build fixed cost, such as a vehicle, labor, etc.
D^j	Market demand in mode j
π_m^j	Firm m's profit in mode j
Decisions	
s^j	Unit installation service level in mode j, $s^j > 0$
p^j	Unit retail price offered by e-retailer in mode j
w^j	Unit logistics service price offered by LSP in mode j
t^j	Unit total service price including logistics delivery and installation service offered by LSP
f^j	Unit installation service price offered by ISP
Superscripts	
E	Home furnishing e-retailer mode
I	Installation service provider mode
L	Logistics service provider mode
Subscripts	
m	Market players, where $m = \mathrm{e}, \mathrm{i}, \mathrm{l}$, represents the e-retailer, LSP, and ISP, respectively

①http://www.chinawuliu.com.cn/zixun/202007/10/514235.shtml.

② https://baijiahao.baidu.com/s?id=1716853630613728916&wfr=spider&for=pc.

DOI: 10.52396/JUSTC-2021-0282
JUSTC, **2023**, 53(1): 5

logistics service level and unit logistics service cost, and then determines the logistics service price that maximizes its profit π_l^E. Corollary 4.1(ii) shows that, with a decrease in k or an increase in β, the e-retailer raises the installation service level s^E, further leading to an increase in retail price p^E. The positive effect of increasing s^E outweighs the negative effect of increasing p^E. Consequently, D^E and π_e^E, π_l^E increase.

4.2 Mode I

In mode I, the LSP provides the logistics service and the e-retailer outsources the installation service to the ISP. The profits of the e-retailer, LSP, and ISP are as follows:

$$\pi_e^I = (p^I - w^I - f^I)(a - p^I + (l + \beta s^I)), \tag{4}$$

$$\pi_l^I = (w^I - c)(a - p^I + (l + \beta s^I)), \tag{5}$$

$$\pi_i^I = f^I(a - p^I + (l + \beta s^I)) - \frac{1}{2}k(s^I)^2. \tag{6}$$

We solve this game using backward induction and obtain the equilibrium results.

Proposition 4.2. In mode I, the equilibrium results are as follows:

$$p^I = \frac{5k(a-c+l)+c(6k-\beta^2)}{6k-\beta^2}, w^I = \frac{2k(a-c+l)+c(6k-\beta^2)}{6k-\beta^2},$$
$$f^I = \frac{2k(a-c+l)}{6k-\beta^2}, s^I = \frac{\beta(a-c+l)}{6k-\beta^2},$$

$$D^I = \frac{k(a-c+l)}{6k-\beta^2}, \pi_e^I = \frac{k^2(a-c+l)^2}{(6k-\beta^2)^2}, \pi_l^I = \frac{2k^2(a-c+l)^2}{(6k-\beta^2)^2},$$
$$\pi_i^I = \frac{k(a-c+l)^2(4k-\beta^2)}{2(6k-\beta^2)^2}.$$

Proposition 4.2 states that as the market potential a and logistics service level l increase, the equilibrium results increase. In addition, as the unit fixed logistics cost c increases, the equilibrium logistics service price w^I increases, and the installation service price f^I, logistics service level s^I, demand D^I, and firms' profits π_e^I, π_l^I, π_i^I decrease.

Corollary 4.2. f^I, w^I, p^I, s^I, D^I, and profits (π_e^I, π_l^I, π_i^I) increase with the installation service level sensitivity (β) and decrease with the installation service cost factor (k).

Corollary 4.2 shows that with a decrease in k or increase in β, the ISP raises the installation service level s^I, leading to a higher installation service price f^I for more profit. Meanwhile, the LSP raises the installation service price w^I considering its profit maximization and the optimal response of the ISP simultaneously. Thus, the e-retailer also raises the retail price p^I to pay higher fees. Similarly, the positive effect of decreasing k or increasing β outweighs the negative effect of increasing price. Consequently, demand D^I and profits π_e^I, π_l^I, π_i^I increase.

4.3 Mode L

In mode L, the LSP undertakes integrated logistics delivery and installation service. The profits for the e-retailer and the LSP are as follows:

$$\pi_e^L = (p^L - t^L)(a - p^L + \theta(l + \beta s^L)), \tag{7}$$

$$\pi_l^L = (t^L - c)(a - p^L + \theta(l + \beta s^L)) - \frac{1}{2}k(s^L)^2. \tag{8}$$

We solve this game using backward induction and obtain the equilibrium results.

Proposition 4.3. In mode L, the equilibrium results are as follows:

$$p^L = \frac{3k(a-c+l\theta)+c(4k-\beta^2\theta^2)}{4k-\beta^2\theta^2},$$
$$t^L = \frac{2k(a-c+l\theta)+c(4k-\beta^2\theta^2)}{4k-\beta^2\theta^2},$$
$$s^L = \frac{\beta\theta(a-c+l\theta)}{4k-\beta^2\theta^2},$$

$$D^L = \frac{k(a-c+l\theta)}{4k-\beta^2\theta^2}, \pi_e^L = \frac{k^2(a-c+l\theta)^2}{(4k-\beta^2\theta^2)^2}, \pi_l^L = \frac{k(a-c+l\theta)^2}{2(4k-\beta^2\theta^2)}.$$

Proposition 4.3 shows that as the market potential a and logistics service level l increase, the equilibrium results also increase. Proposition 4.3 also indicates that as the unit fixed logistics cost c increases, the equilibrium logistics service level s^L, demand D^L, firms' profits π_e^L, π_l^L decrease.

Corollary 4.3. The decrease of installation service cost factor (k) or increase of installation service level sensitivity (β) will increase t^L, p^L, s^L, D^L, and profits (π_e^L, π_l^L) under mode L.

Corollary 4.3 shows that with a decrease in k or an increase in β, the LSP's installation service level s^L, total service price t^L, and the e-retailer's retail price p^L all increase. For the same reason as Corollary 4.2, demand D^L and profits π_e^L, π_l^L increase.

Corollary 4.4. t^L, p^L, s^L, D^L, and profits (π_e^L, π_l^L) will increase with the delivery service preference (θ).

As delivery service preference θ increases, the effectiveness of joint logistics and installation services increase. Thus, the impact of the installation service level s^L on the demand D^L increases, and the LSP raises the total service price t^L for greater profit π_l^L. Thus, the e-retailer increases the retail price p^L for higher profit π_e^L.

5 Comparison and analysis

In this section, we compare the decision variables and profits for all modes. By analyzing the optimal results, we found that the results crucially depend on the installation service's cost performance (i.e., $\tau = \frac{\beta^2}{k}$). The combined parameter τ measures the investment efficiency of an installation service. A larger τ indicates that the unit investment in the installation service can bring more demand. Furthermore, it can reflect the individual impacts of demand sensitivity on the installation service level (β) and installation service cost factor (k)[41].

Corollary 5.1. The impact of logistics service unit cost (c) on equilibrium results are as follows:

(i) When $\tau < \frac{2}{\theta^2}$, t^L will increase with c; when $\tau > \frac{2}{\theta^2}$, will decrease with c.

DOI: 10.52396/JUSTC-2021-0282
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(ii) When $\tau < \frac{1}{\theta^2}$, p^E, p^I, and p^L will increase with c; when $\frac{1}{\theta^2} < \tau < 1$, p^E and p^I will increase with c and p^L will decrease with c; however, when $\tau > 1$, p^E, p^I, *and* p^L will decrease with c.

Corollary 5.1 shows interesting results in that the impacts of the logistics service unit cost c on retail price p and the total service price t^L are dependent on the installation service's cost performance τ. Intuitively, the total service price will increase because the logistics service cost increases with c; however, Corollary 5.1(i) states that in mode L, the total service price decreases with the logistics service unit cost when the installation service's cost performance is relatively high. This is because the effect of the installation service level dominates when the installation service's cost performance is high, and the LSP charges a lower price by jointly optimizing the logistics and installation service pricing decisions. Corollary 5.1(ii) indicates that as the logistics service unit cost increases, the e-retailer charges higher prices when the installation service's cost performance is relatively low, but charges lower prices when the installation service's cost performance is relatively high. The huge service cost motivates the e-retailer to raise the retail price when the installation service's cost performance is low. However, when the installation service's cost performance is high, the effectiveness of the installation service level plays a major role; the e-retailer charges lower prices as the logistics service unit cost increases, achieving higher profit.

Proposition 5.1. The optimal installation service levels among modes E, I, and L satisfy: $s^L > s^E > s^I$ if $0 < \tau < \tau_s^{LE}$; $s^E > s^L > s^I$ if $\tau_s^{LE} < \tau < 2$ (τ_s^{LE} is given in Appendix A of the supporting information).

Proposition 5.1 shows that Mode I generates the lowest installation service level. The rationale lies in the fact that under mode E, the e-retailer not only takes pricing power, but also directly controls the installation service level. Compared with mode I, the total service price and installation service level are jointly controlled by the LSP, resulting in a lower double marginalization effect and, consequently, a higher installation service level under mode L. However, in mode I, the e-retailer yields the control power of the installation service to the ISP, leading to a more severe double marginalization effect and, consequently, a lower installation service level.

Moreover, mode L generates the highest installation service level when the installation service's cost performance is low; otherwise, mode E generates the highest service level. The rationale lies in the fact that when the e-retailer outsources the installation service to the LSP, customers' delivery service preference motivates the LSP to provide a higher installation service level, even though the e-retailer yields the control power of the installation service to the LSP, leading to a double marginalization effect. In mode E, the service level is mainly affected by the installation service's cost performance. When the installation service's cost performance is low, the effect of the installation service level on demand decreases, and the negative impact of the cost will play a major role, leading to a lower service level. The increment in profit is not sufficient to compensate for the decrease in the installation service cost, so the e-retailer reduces the service level. As the installation service's cost performance increases, the effect of the installation service level on demand increases, and the positive impact of the service level on the profit exceeds the negative impact of the service level on the cost; thus, the e-retailer has more incentive to improve the installation service level.

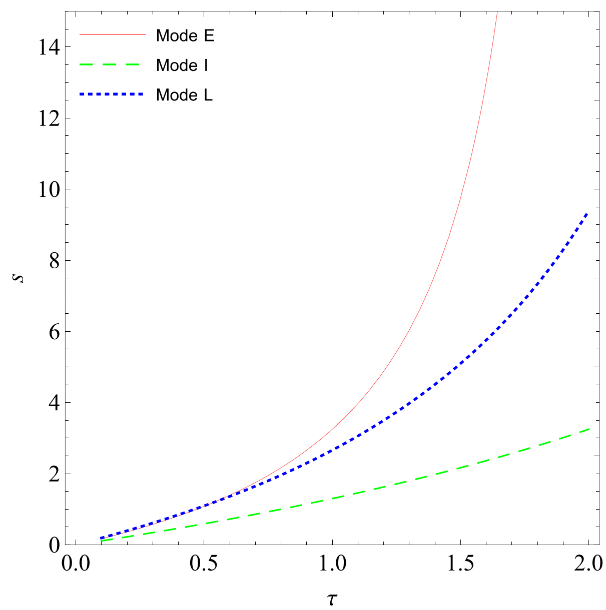

Fig. 2. Installation service levels in different modes.

We assume the parameters $a = 10$, $c = 2$, $l = 5$, $\beta = 2$, and $\theta = 1.1$. Fig. 2 describes the trend of the installation service level on the installation service's cost performance and provides visual descriptions for Proposition 5.1. As shown in Fig. 2, the ISP provides the lowest service level in mode I. When the installation service's cost performance is low, the LSP provides the highest installation service level. As the installation service's cost performance increases, the installation service level is significantly affected by the installation service's cost performance in mode E; thus, the e-retailer provides the highest installation service level.

Proposition 5.2. The equilibrium retail prices among modes E, I, and L satisfy (τ_p^{LE} and τ_p^{IL} are given in Appendix A of the supporting information):

(i) When $1 < \theta < 1 + \frac{(a-c+l)}{9l}$, $p^E < p^L < p^I$ if $\tau < \tau_p^{IL}$; $p^E < p^I < p^L$ if $\tau_p^{IL} < \tau < 1$; $p^I < p^E < p^L$ if $1 < \tau < \tau_p^{LE}$; $p^I < p^L < p^E$ if $\tau > \tau_p^{LE}$;

(ii) When $\theta > 1 + \frac{(a-c+l)}{9l}$, $p^E < p^I < p^L$ if $\tau < 1$; $p^I < p^E < p^L$ if $1 < \tau < \tau_p^{LE}$; $p^I < p^L < p^E$ if $\tau > \tau_p^{LE}$.

Proposition 5.2 shows that mode E generates the lowest retail price when the installation service's cost performance is less than 1; otherwise, mode I generates the lowest retail price. The key driver is the trade-off between the impacts of the double marginalization effect and the installation service level on the retail price. On the one hand, the double marginalization effect correspondingly results in a higher retail price. On the other hand, a lower installation service level leads to a lower retail price. Moreover, the impact of the installation service level on retail price depends on the effectiveness of

DOI: 10.52396/JUSTC-2021-0282
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the installation service. Specifically, when the installation service's cost performance is low, the double marginalization effect plays a dominant role, resulting in a lower retail price in mode E. In contrast, when the installation service's cost performance is high, the effect of the installation service level plays a major role, leading to a lower retail price in mode I.

Furthermore, Proposition 5.2 indicates that if customers' delivery service preference is relatively low, mode L will generate the highest retail price when the installation service's cost performance is in the medium range. However, once customers' delivery service preference is relatively high, mode L generates the highest retail price when the installation service's cost performance is relatively low. This is because, when customers' delivery service preference is relatively high, the impact of the installation service level on market demand increases, leading to a major effect on the service level. Therefore, mode L generates a higher retail price than mode I. However,mode L does not always generate the highest retail price. This is because the double marginalization effect plays a major role in leading to a higher retail price in mode I when the installation service's cost performance is relatively low. As the installation service's cost performance increases, the impact of the installation service level on the retail price increases, leading to retail price changes in line with the service level.

Fig. 3 provides visual descriptions of Proposition 5.2. It is drawn with the parameters $a = 10$, $c = 2$, $l = 5$, $\beta = 2$, $\theta = 1.1$, and $\theta = 1.3$. We can intuitively see that prices increase with the installation service's cost performance. In Fig. 3, we can see that the retail price can also be affected by the delivery service preference under mode L, and the retail price under mode E changes quickly when the customers' delivery service preference is relatively low. However, the e-retailer generates the highest price in mode L when the customers' delivery service preference is relatively high.

Proposition 5.3. Home-furnishing e-retailer's profits among different modes satisfy the following relationships (τ, $\breve{F}_1$, and $\breve{F}_2$ are given in Appendix A of the supporting information):

(i) When $\tau < \tau$, $\pi_e^L > \pi_e^E > \pi_e^I$ if $F < \breve{F}_2$; $\pi_e^L > \pi_e^I > \pi_e^E$ if $F > \breve{F}_2$.

(ii) When $\tau > \tau$, $\pi_e^E > \pi_e^L > \pi_e^I$ if $F < \breve{F}_1$; $\pi_e^L > \pi_e^E > \pi_e^I$ if $\breve{F}_1 < F < \breve{F}_2$; $\pi_e^L > \pi_e^I > \pi_e^E$ if $F > \breve{F}_2$.

Proposition 5.3 indicates that the e-retailer does not achieve the highest profit in mode I. This outcome occurs because by jointly optimizing the logistics delivery and installation service pricing decision and the service investment, the e-retailer generates a larger demand and a higher profit in mode L. In mode E, the e-retailer controls the installation service level and pricing, leading to higher profit. The impact of the double marginalization effect and the installation service level on the profit, the e-retailer yields control power over the installation service to the ISP, leading to a more severe double marginalization problem, and a lower installation service level will generate a lower profit.

Furthermore, Proposition 5.3 shows that the e-retailer can only achieve the highest profit in mode E when the installation service's cost performance is higher and the self-build fixed cost F is relatively low; otherwise, the e-retailer achieves the highest profit in mode L. The rationale lies in the fact that there are interactions between the installation service's cost performance and the self-build fixed cost. When the installation service's cost performance is relatively low, the installation service level and retail price under mode L are higher, and the effect of the installation service level on profit increases the profit under mode L. When the installation service's cost performance is relatively high, as the effectiveness of the installation service level increases, a higher installation service level leads to a higher profit in mode E when the self-build fixed cost is low. However, if the self-build fixed cost is too high and the revenue is not sufficient to compensate for this part of the fixed expenditure, the e-retailer will obtain a lower profit.

Fig. 4 provides a visual description of the e-retailer's mode

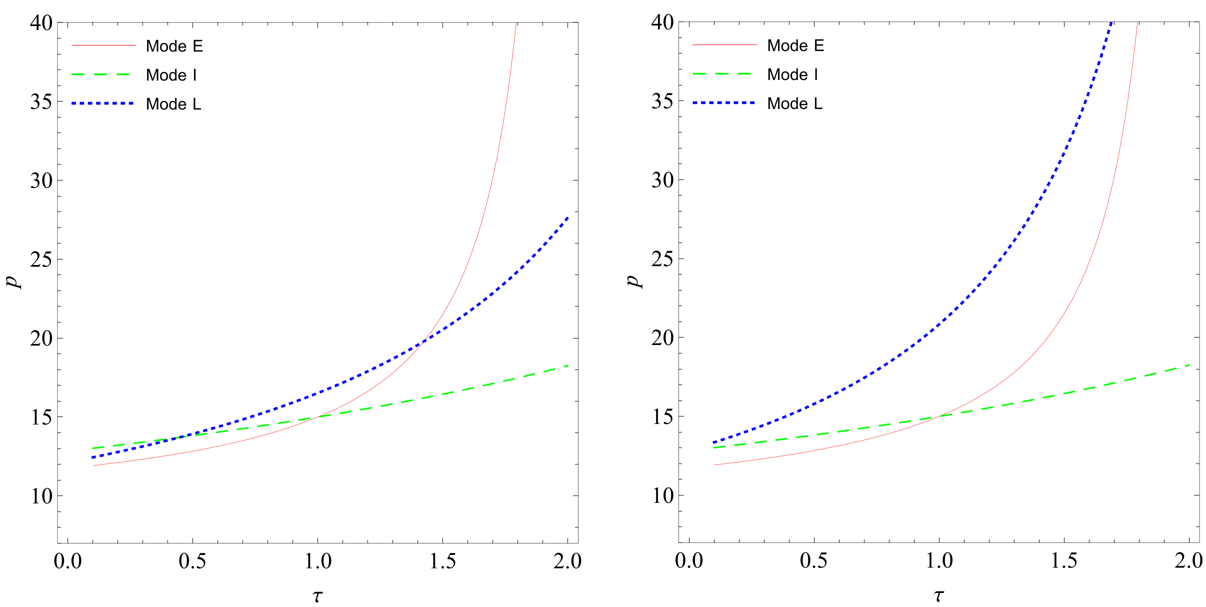

Fig. 3. Retail prices in different modes.

DOI: 10.52396/JUSTC-2021-0282
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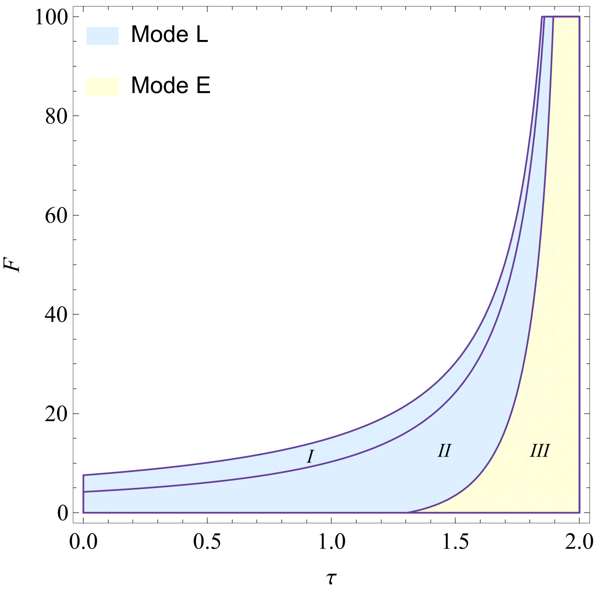

Fig. 4. The home-furnishing e-retailer's preference: interactions between τ and F.

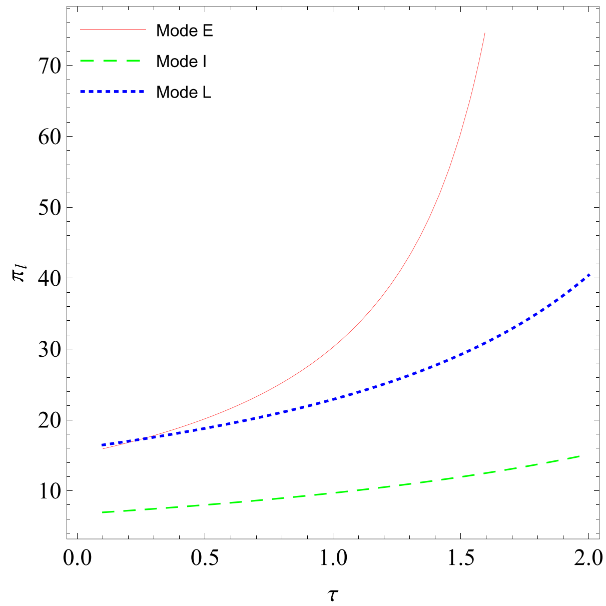

Fig. 5. LSP's profits in different modes.

selection under the three modes. It is drawn with the parameters $a=10$, $c=2$, $l=5$, $\beta=2$, and $\theta=1.1$. As illustrated in Fig. 4, when the installation service's cost performance is low, the e-retailer prefers the integrated delivery service mode (i.e., mode L), which are part I and part II (part I is that mode I is better than mode E; part II is that mode E is better than mode I). Otherwise, the e-retailer prefers the self-build installation service mode (mode E), which is part III.

These conclusions are consistent with those of actual practice. In 2020, the home-furnishing industry became the biggest dark horse, and the number of orders rose 61%, against the trend; in the first hour of sales in the electrical appliance industry, 25 brands achieved a tenfold increase in transactions. Since 2013, Alibaba has gradually built home delivery and installation integration services with large-scale logistics leaders, such as the RRS and Suning Logistics. In nearly 3000 districts and counties across the country, 100% door-to-door and pre-order deliveries have been achieved, which has solved the most troublesome problem for customers when buying products. This also explains the significant increase in transactions.

Corollary 5.4. The service prices of the LSP among different modes always hold $w^{E}<w^{I}<t^{L}$.

Corollary 5.4 shows that, under Mode L, the LSP has the highest service price. This is because, under mode L, the LSP's service price includes not only the logistics delivery price, but also the installation service price. When considering the optimal response decision of the ISP, the LSP charges a higher service price in mode I than in mode E.

Proposition 5.4. The LSP's profits among different modes satisfy the following relationships: $\pi_1^{I}<\pi_1^{E}<\pi_1^{L}$ if $0<\tau<\breve{\tau}$; when $\pi_1^{I}<\pi_1^{L}<\pi_1^{E}$ if $\breve{\tau}<\tau<2$ ($\breve{\tau}$ is given in Appendix A of the supporting information).

Proposition 5.4 shows that when the installation service's cost performance is relatively low, mode L will generate the highest profit; otherwise, mode E will generate the highest profit. Moreover, the LSP always generates the lowest profit in mode I. This is because the LSP's profit in mode I or mode E is only derived from the logistics service, whereas in mode L, it is derived from the logistics delivery and installation service. Although mode E always generates the lowest logistics service price, the installation service level and demand under mode I are always the lowest among the three modes, and the LSP in mode E will generate more profit. Under mode L, the LSP's income comes from two parts: logistics delivery and installation service, but an additional variable cost is added because it provides an installation service. When the cost performance is relatively high, even if mode L generates the highest service price, the variable cost increases and the demand in mode E will be higher. Therefore, the LSP obtains the largest profit in mode E.

We assume the parameters $a=10$, $c=2$, $l=5$, $\beta=2$, and $\theta=1.1$. Fig. 5 describes the trend of the LSP's profits on the installation service's cost performance under the three modes and provides visual descriptions for Proposition 5.4.

Proposition 5.5. The optimal delivery mode selections for the e-retailer and the LSP are as follows:

(i) If $\tau>\max\{\breve{\tau},\tilde{\tau}\}$ and $F<\breve{F}_1$, both the e-retailer and the LSP prefer mode E.

(ii) If $\tau>\max\{\breve{\tau},\tilde{\tau}\}$ and $F>\breve{F}_1$, or $\tau<\min\{\breve{\tau},\breve{\tau}\}$, both the e-retailer and the LSP prefer mode L.

Proposition 5.5 shows the win-win range for the e-retailer and the LSP to choose modes E and L. When the installation service's cost performance is high and the self-build fixed cost of the e-retailer is low, the e-retailer should choose mode E. When the installation service's cost performance is low or when the self-build fixed cost is high if the installation service's cost performance is in a high range, the e-retailer should choose mode L.

6 Extensions

In the base model, we assume that logistics delivery is commonly outsourced to professional LSPs. In practice, famous e-retailers, such as JD.com and Amazon, have self-supporting

DOI: 10.52396/JUSTC-2021-0282
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logistics service systems. In this section, we extend the base model to a scenario where e-retailers have self-supporting logistics service systems. The results reveal that under the self-build installation service, the e-retailer's profit is higher under the self-build integrated delivery service mode (mode S) than under the outsourced separated delivery service mode (mode E). Furthermore, we find that under providing the integrated service, if the self-build fixed cost is too high, the e-retailer will prefer the outsourced integrated delivery service mode (mode L) rather than the self-build integrated delivery service mode (mode S). The preferred modes for the base and extended models are compared and summarized in Table 2. All analyses are provided in Appendix B of the supporting information.

We use superscript S to represent mode S, in which the e-retailer undertakes the self-build integrated logistics delivery and installation services. Comparing mode S with modes E and L in our base model, we find that mode S is always better than mode E when considering a self-build installation service. Compared with mode E, the customers' delivery service preference motivates the e-retailer to provide a higher installation service level, leading to higher demand and a higher profit under mode S. However, when considering integrated services, mode S is better than mode L only when the self-build fixed cost is low; otherwise, mode L is better than mode S. The rationale is that the e-retailer yields the control power of the installation service to the LSP, leading to a double marginalization effect; thus mode S generates a higher profit when the self-build fixed cost is low. When the self-build fixed cost is too high, the revenue is not sufficient to compensate for this part of the fixed expenditure; the e-retailer will obtain a lower profit and prefer mode L.

7 Conclusions

With the rapid development of the online home-furnishing industry market, customers are paying more attention to the installation of home-furnishing products. They expect prompt and seamless delivery services and convenient online ordering experience. In this study, we innovatively introduced delivery mode selection based on a combination of logistics delivery and installation services. We establish a game model and, through the selection of ISPs, we analyze three modes: The e-retailer undertakes the installation service (mode E); the ISP undertakes the installation service (mode I); the LSP undertakes the installation service (mode L). We then obtain the optimal installation service level, retail price, and the optimal mode of home-furnishing e-retailer. It provides theoretical support for home-furnishing e-retailers and LSPs to solve the delivery of home products, especially the installation of value-added services, thus improving customer satisfaction.

First, intuitively, to stimulate demand and promote profits, the e-retailer would provide a better installation service than a third party. However, in this study, we find that the LSP could also benefit customers with a higher level of service. Second, we find that the self-build installation service mode generates the lowest retail price if, and only if, the installation service's cost performance is relatively low. This was mainly affected by the effectiveness of the installation level. In particular, the retail price can also be affected by delivery service preferences in mode L. The higher the delivery service preference, the higher the retail price. Moreover, we find that firms' profitability aligns with improvements in installation service level. The rationale lies mainly in the impact of the installation service's cost performance on the double marginalization effect in the supply chain. For the e-retailer, considering the self-build fixed cost of installation service, when the installation service's cost performance is relatively high, the e-retailer will choose a self-build installation service if, and only if, the self-build fixed cost is relatively low; otherwise, the e-retailer will choose an integrated logistics delivery and installation service (mode L). The LSP will provide integrated delivery only when the installation service's cost performance is relatively low; otherwise, it tends to cooperate with the e-retailer that provides the self-build installation service. Finally, we find that under certain conditions, both mode E and mode L can enable the e-retailer and the LSP to achieve win-win situations; therefore, the e-retailer and the LSP can choose the optimal delivery mode according to the principle of maximum profit. In the extension, we find that, compared with the outsourced integrated service mode, the integrated service mode under the self-supporting logistics system cannot be a better choice for the e-retailer if the self-build fixed cost is too high.

Although our study provides new managerial insights into home-furnishing e-retailers, there are some limitations. First, the logistics service level in our study is assumed to be determined. However, LSP usually can provide different logistics service levels, and it would be interesting to examine the optimal logistics service level in different service modes. Moreover, we assume that the installation network coverage of installation services provided by each member of the supply chain is 100%; in fact, most emerging LSPs' integrated delivery service network coverage has not reached 100%. Hence, the selection of e-retailer delivery modes may change, which is also the direction of our future research. Finally, our paper only theoretically demonstrates the conditions under which the e-retailer benefits from the integrated logistics delivery and installation service. It is promising to examine the analytical results using empirical data and explore how home-furnishing e-retailers choose the different modes considering the impact of interactions between the installation service's cost performance and the self-build fixed cost.

Table 2. The preferred modes for the base and extended models.

Conditions/Modes	S vs. E	S vs. L
Low fixed self-built cost	S	S
High fixed self-built cost	S	L

Supporting information

The supporting information for this article can be found online at http://doi.org/10.52396/JUST-2021-0282. The supporting information includes the proofs of all the propositions and corollaries.

DOI: 10.52396/JUSTC-2021-0282
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Acknowledgements

This work was supported by the National Natural Science Foundation of China (71991464/71991460, 71921001) and the Fundamental Research Funds for the Central Universities (WK2040000027).

Conflict of interest

The authors declare that thet have no conflict of interest.

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DOI: 10.52396/JUSTC-2021-0282
JUSTC, **2023**, 53(1): 5