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A game theory analysis of intelligent transformation and sales mode choice of the logistics service provider

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ABSTRACT

In order to study whether the logistics service provider (LSP) should carry out intelligent transformation strategy of logistics services, this paper constructs a logistics service supply chain consisting of one LSP and one logistics service integrator (LSI), and discusses whether the LSP is independent or participate in LSI. The paper shows that choosing the intelligent transformation of logistics services under any mode can improve the profits of the LSP and the LSI. The joint transformation of logistics services to improve the profit of the LSI is not affected by the choice of mode, while the profit of LSP under the resale mode remains unchanged when she chooses joint intelligent transformation. When the intelligent transformation level is high, the LSI tends to choose the resale model; otherwise, the LSI tends to choose the platform model. When the LSP chooses intelligent transformation by herself, if the share ratio is low, the LSI tends to choose the resale model. If the share ratio is high and the level of intelligent transformation of logistics services is not high, the LSI more inclines to choose the platform model.

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Keywords:
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1. Introduction

With the growing specialization, customization, and diversification of customer needs, the large-scale customized logistics service model emerges as the times require [1]. Under this kind of logistics service mode, logistics enterprises spontaneously form a LSSC logistics service supply chain through alliance and integration, and use the scale effect to reduce logistics service costs and meet the increasingly rich service needs of customers as much as possible under certain cost constraints [2, 3]. According to different functions, the LSSC mainly includes LSPs that provide basic logistics functions such as transportation, packaging, and warehousing, LSIs that integrate various basic logistics services, and final logistics service demand customers [3, 4]. Numerous studies have shown that under the background of mass customization, it is very effective to

achieve specific goals of logistics service needs through LSIs in the LSSC and customers, and to use the basic functions of LSPs to finally meet customers' logistics service requirements [3, 5, 6].

The efficiency of the logistics service system can effectively solve the different types of service needs of customers and meet the challenges brought by changes in demand. In the operation process of enterprises, to improve the operational efficiency of logistics services, enterprises try to adopt emerging technologies such as cloud computing, the Internet of Things, big data, block-chain, etc. [7], the traditional mode of logistics has been subverted, and intelligent logistics has entered the era of logistics 4.0 under the background of Industry 4.0 [8, 9]. Based on traditional logistics, intelligent logistics uses modern intelligent information technology and intelligent equipment to identify and perceive all aspects of the logistics system, to achieve efficient control of the entire logistics system, and to make decisions that better meet customer needs [10]. Intelligent logistics has been widely used in many enterprises and achieved good results. For example, DHL integrates the Internet and autonomous driving technology in the logistics business and is responsible for the dedicated innovation center [11], JD Logistics is already experimenting with package delivery via drones in Xi'an [12], Cainiao relies on an intelligent logistics network to achieve the goal of 72-hour delivery of products [13]. Consumers' demands for functions such as visualization and personalization have prompted logistics companies to pay more attention to logistics service innovation.

Consumers' demands for functions such as visualization and personalization have prompted logistics companies to pay more attention to logistics service innovation. Through the intelligent logistics model, it is helpful to renew the supply chain, realize the high added value of products, high operation efficiency, and shorten the supply cycle, to obtain the active advantage of the market and realize the growth of profits [14, 15]. The intelligent transformation of logistics services is crucial to the development of an enterprise and even determines whether an enterprise can exist [3]. LSPs are usually initiated in the process of intelligent transformation of LSSCs, mergers and acquisitions guide logistics service integrators to participate through a series of incentive measures. The intelligent transformation process of LSSC is usually initiated by LSIs, and guides LSPs to participate through a series of incentive measures [16]. The intelligent transformation of logistics services can upgrade traditional logistics services. In the process, LSIs can reduce the cost of logistics services and improve operational efficiency [17], while LSPs can obtain more orders. For example, Cainiao, as one LSI of Taobao and Tmall supermarkets, integrates many functional logistics providers to provide services. Among them, YTO Express uses advanced technology and equipment in the service process, improves service processes, provides comprehensive warehousing and distribution and logistics network Expasion and other value-added ser-vices to meet product delivery. Therefore, Cainiao allocates more logistics service orders to YTO Express. However, it is a long-term task for logistics service providers to carry out intelligent logistics transformation. During the transformation process, additional values such as logistics service design, introduction of advanced technology and equipment, and maintenance all require additional costs. Uncertainty of investment and profit will be enthusiastic about the intelligent transformation of logistics service providers. Whether LSIs allow LSPs to independently trans-form intelligently or encourage LSPs to jointly intelligently transform? At the same time, in the context of the Internet economy, online platforms have become a common business model. For example, Amazon, JD.com, Suning.com in the retail industry, ransfarzl.com, aisup-port.express.cainiao.com, and huolala.cn in the logistics service industry, etc. The platform model and the resale model have become the most typical and common operating models in the Internet environment [18]. Under the platform mode, LSIs provide LSPs with places to directly connect with customers, while under the resale mode, LSIs purchase LSPs' logistics resources and serve consumers. In practice, logistics service efficiency will be a key factor for decision-makers to adopt a platform model or a resale model [19]. In the process of intelligent transformation of LSPs, whether the adoption of different models affect the transformation of intelligent logistics services?

Motivated by the above issues, this paper constructs a platform-involved LSSC, including one LSI and one LSP, we discuss the selection of intelligent transformation of the LSP under the background of the LSI launching joint logistics service intelligent transformation. This paper mainly answers the following two questions:

(1) Is the LSP going to undergo intelligent transformation? If the LSP chooses intelligently transformed, does she stand alone or join the joint intelligent transformation plan of the LSI?
(2) Are there differences in the decision-making process between the platform model and the resale model, and which model is more beneficial for both parties to choose in different decision-making processes?

The main contributions of this paper are the following three points. First, from the perspective of enterprise strategic transformation, this study not only considers consumer promotion but also considers the intelligent transformation of LSPs driven by LSIs, and analyzes the impact of intelligence level and supply chain incentives on strategic choices. Second, in this study, we have drawn many interesting conclusions about the platform model introduced under the Internet economy in the process of analyzing the intelligent transformation of logistics services. Third, this study has strong practical guiding significance for the intelligent transformation of convection services. For example, LSIs can adjust the LSPs' behavior of intelligent logistics transformation by manipulating the share ratio.

The rest of this paper is organized as follows. Section 2 reviews the relevant literature on intelligent logistics, selling mode choice and, LSSC. In section 3, under the platform mode and reselling mode, we constructed and solved the model in six scenarios including basic services provided by the LSP, intelligent transformation of independent, and joint transformation of logistics services. In section 4, we make a comparative analysis combined with numerical simulation, and section 5 concludes this paper. Finally, we give the relevant proof in Appendix A.

2 Literature review

The literature related to this paper includes the following three streams: intelligent logistics, sales mode choice and, LSSC.

The first stream lies in intelligent logistics. Intelligent logistics is a form of logistics service that ensures the entire supply chain is more intelligent and automated with the help of various advanced technologies [9]. Some scholars began to pay attention to the technology of improving the efficiency of logistics systems, such as RFID technology [20], IoT technology [21], blockchain technology [22, 23], and big data technology. The use of intelligent logistics can improve service efficiency, reduce costs, and gain first-mover advantages in the market, which is an inevitable trend in the development of modern logistics [20, 24]. Some scholars have conducted related research from the perspective of the government's policy support for the development of intelligent logistics [9, 25] and the future development trend of intelligent logistics [8, 10]. At present, the research on intelligent logistics has been extended to various scenarios. For example, the least squares method for the shortest path problem of port intelligent logistics based on cloud technology [26]; improved the algorithm problem for optimizing end-of-line delivery vehicle routing [27]; a hybrid agent scheduling and synchronization approach to solve the optimization problem of the intelligent logistics system [28], and an intelligent warehouse management approach based on machine vision and the Internet of Things (IoT) [29]. At the same time, some scholars have studied the intelligent transformation of logistics services through game theory methods [30-33]. Different from the above research, the focus of this paper is to study whether this LSP is driven by consumers to undergo intelligent transformation, or whether it is driven by the LSI alone or jointly with intelligent transformation, and mainly discusses consumption stimulation and the LSI's incentive effects.

The second stream lies in sales mode choice. Due to the development of the e-commerce economy, the comparative study on the coexistence of the platform model and the resale model has attracted more and more scholars' attention. Abhishek *et al*. [18] conducted a comprehensive study of the platform model and the resale model. Some scholars have also conducted related research on pricing and channel entry under the two models. For example, Yan *et al*. [34] considered the pricing decision of manufacturers under the platform model and the resale model and found that whether a retailer joins the platform depends on the platform fee. Zhang *et al*. [35] studied the supplier channel expansion problem in two modes. He *et al*. [36] studied the

sales model and pricing of the tourism O2O supply chain. Xu *et al*. [37] researched that demand is influenced by consumers' green preferences and manufacturers' pricing and carbon emission reduction decisions under the platform model and resale model. Liu *et al*. [38] studied the different sales models and prices of fresh food, and considered channel competition and the application of blockchain technology in the process of research. Liu *et al*. [39] considered both the service model and the sales model and analyzed which model is optimal. Geng *et al*. [40] discussed the relationship between different sales models and supply chain members. Some scholars have also studied the sales system of online sales platforms [41].

In the process of product sales, logistics service is an important factor, some scholars have considered logistics service strategies in the comparative study of the two models [42-44]. The platform model and the resale model are two commonly used sales models in the e-commerce environment, but so far there are few studies on the differences in the sales model of the LSSC. This research explores the influence of logistics service intelligence level on sales mode, the influence of different modes on service cooperation between the two parties, and the relationship between share ratio and intelligent logistics service level.

The third stream lies in LSSC. Scholars' research on LSSC mainly focuses on logistics service quality, pricing, and procurement decision-making, and will consider the fair preference of supply chain members, risk aversion or social responsibility, and other behavioral factors, as well as demand uncertainty, demand update, and demand interruption, etc. factor into the model. For example, Liu *et al*. [45] studied how to determine the revenue-sharing coefficient of LSSC under random conditions. Yunmiao *et al*. [46] analyzed the problem of contract coordination selection when the demand of LSSC is uncertain. Liu *et al*. [3] studied the LSSC scheduling problem under the environment of mass customization and uncertain operation time. Liu *et al*. [47] analyzed the coordination problem of LSSC when demand is disturbed. Wang *et al*. [48] and Liu *et al*. [49] took the fairness preference factor into account in the model, and analyzed the contract coordination and order allocation decision-making problems in the LSSC, respectively. Liu *et al*. [6] discussed the optimal decision-making of member enterprises in the LSSC based on different decision-making modes under the background of "One Belt, One Road". Qin *et al*. [50] studied the service quality coordination problem of the online shopping service supply chain based on fairness and individual rational preference. Niu *et al*. [51] explored the role of the Internet of Things in the context of sustainable and traceable functions of logistics services with the help of game theory. Different from them, this paper mainly studies whether the logistics service is intelligently transformed, how to transform it, and how to sell it. Kin and Ha [52] analyzed the differences between the manufacturing supply chain and the LSSC.

According to our review of relevant literature, we found that intelligent logistics has aroused the research interest of many scholars. This literature has a great reference for us, but there are still gaps. Relevant to our study are [30, 32], they mainly focused on logistics services integration transformation contract, while we considered the transformational impact of the LSI providing cost sharing on the LSP. At the same time, they did not consider the choice of sales model during the transformation of the LSP. Combined with the above analysis, the existing research cannot solve the problem we raised. In addition, this paper also considers the intelligent transformation of logistics services and the decision-making of sales model selection and provides more theoretical decision-making references for the intelligent transformation of LSSCs.

3. Model construction and analysis

3.1 Model construction

This paper considers the LSSC involved in the platform, and its logistics service requirements are completed by one LSI and one LSP. The LSI joins the supply chain service platform and pays the franchise fee, integrates and publishes the demand information of logistics services, and the LSP completes the tasks according to the needs of customers. The modes adopted when the LSI and the LSP cooperate include resale mode and platform mode. In the platform mode, the LSP provides services to customers in the form of third-party logistics according to the requirements of the LSI and pays u proportion of the commission, as shown in Fig. 1. In the resale mode, the

logistics service is wholesaled to the LSI at the wholesale price w, and the LSI determines the final logistics service price p, as shown in Fig. 2. In the above two modes, the LSP will consider whether to carry out intelligent transformation according to the requirements of the LSI. In the case of independent transformation, the LSP shall bear the cost of intelligent transformation, and in the case of joint transformation, the LSI shall share s proportion of the transformation cost.

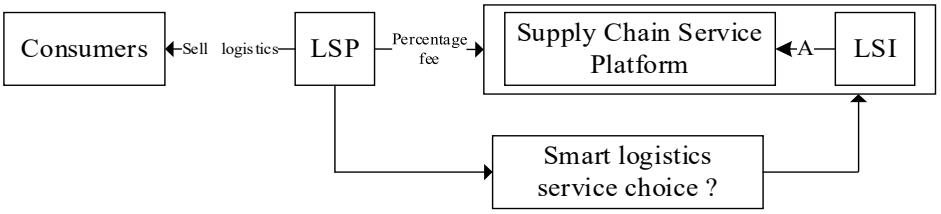

Fig. 1 Platform mode

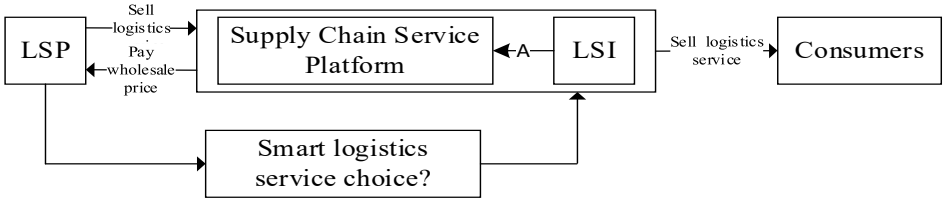

Fig. 2 Resale mode

According to the literature [30, 31], we assume that the cost of intelligent transformation of logistics services is $c(y) = gy^2$, which reflects that with the increase of intelligent logistics service level, the cost will also increase. Among them, g represents the cost-sensitive factor of intelligent logistics service, and the larger the value, the more sensitive it is. We denote $z = m^2/g$ as the efficiency of intelligent logistics service, reflecting the ratio of benefit to cost per unit of intelligent logistics service efficiency. Without loss of generality, similar to the literature [30], we also assume that the marginal cost of logistics services is 0, that is, this paper does not consider the production cost of unit logistics services and other costs other than intelligent logistics services. In the platform model, the revenue share of the LSI is related to the category of logistics services. This paper assumes that the revenue share ratio u is an exogenous variable. To conform to the reality and the profit of the LSI is positive, when the LSI is not provided and the LSP undertakes intelligent logistics transformation alone, the value range of u is $0 < u < 0.5$. When implementing joint intelligent transformation, to ensure that the cost shared by logistics service integrators is positive, the following conditions need to be met: $\frac{-6-2\sqrt{9-2z}+z}{z} < u < 0.5$ and $0 < z < 2$.

Demand. According to the literature [31, 33], when the customer demand is the basic logistics service, the demand function can be expressed as $q = a - p$, among them, a is the basic demand of logistics services, and p is the price of logistics services. In fact, in the actual logistics service operation process, in addition to the basic logistics needs, customers will also require personalized value-added logistics services. To meet the needs of customers, the LSI will propose intelligent logistics transformation, and the LSP will specifically undertake intelligent logistics service tasks. Assuming that under the influence of intelligent logistics, the increase in logistics demand at this time is my, among them, y represents the service level of intelligent logistics, and m represents the sensitivity factor of customers to intelligent logistics services, Therefore, the demand for intelligent logistics services can be expressed as $q = a - p + my$.

Scenarios. Considering the strategic choice of the LSP between the platform model and the resale model, as well as the choice of the intelligent transformation strategy in the face of customer needs, there are 6 possible decision scenarios, as shown in Table 1.

Table 1 Logistics service and sales choice mode in six scenarios

Sales mode	Marketing type		
	Basic logistics	Intelligent logistics by the LSP	Joint Intelligent logistics
Platform mode	PB	PS	PC
Resale mode	RB	RS	RC

- Platform mode with basic logistic service (PB): In this case, the LSI acts as a bridge between consumers and the LSP, and the LSP directly provides consumers with basic logistics services and decides the price p^{PB} of logistics services.
- Platform mode with intelligent logistic service by the LSP (PS): In this case, the LSI proposes a joint intelligent logistics service transformation plan, and the LSP does not participate in the joint plan and decides the transformation level y^{PS} and sales price p^{PS} independently.
- Platform mode with intelligent logistic service by cooperation (PC): In this case, the LSI proposed a joint intelligent logistics service transformation plan, and the logistics service provider decided to participate. First, the LSI decides to share the cost of intelligent logistics transformation, and then the LSP decides the level of intelligent logistics service transformation y^{PC} and sales price p^{PC}.
- Resale mode with basic logistic service (RB): In this case, the LSP resells the service to the LSI. First, the LSP decides the basic logistics service wholesale price w^{RB}, and the LSI decides the final logistics service price p^{RB}.
- Resale mode with intelligent logistic service by LSI (RS): In this case, the LSI proposes a joint intelligent logistics service transformation plan, and the LSP does not participate. First, the LSP decides the wholesale price w^{RS}, then the LSI decides the sales price p^{RS}, finally the LSP decides the intelligence level y^{RS}.
- Resale mode with intelligent logistic service by cooperation (RC): In this case, the LSI proposed a joint intelligent logistics service transformation plan, and the LSP decided to participate. First, the LSP decides the wholesale price w^{RC}, then the LSI decides the sales price p^{RC} and cost-sharing ratio s^{RC}, and finally the LSP decides the intelligence level y^{RC}.

The main notations related to this paper are shown in Table 2. We use the superscript P and R to represent the platform sales model and the resale model, respectively, the superscript *Z to represent the optimal solution, and π_T and π_J to represent the profits of the LSP and the LSI, respectively.

Table 2 The notations related to this paper

Notation	Instruction
a	Market size of the logistics service market
p	Price of the logistics service
q	Demand for the logistics service
m	Consumer's sensitivity of the intelligent logistics service
y	Intelligent level of the logistics service
g	Cost coefficient of intelligent transformation
u	The share ratio of the LSI under a platform mode
w	Wholesale price of the unit logistics service under a resale mode
z	The intelligent transformation efficiency
s	Cost sharing ratio of the intelligent transformation
A	Supply chain platform membership fee
$\pi_T^{PB}(\pi_T^{RB})$	Profit of the LSP in platform mode (resale mode) with basic service
$\pi_J^{PB}(\pi_J^{RB})$	Profit of the LSI in platform mode (resale mode) with basic service
$\pi_T^{PS}(\pi_T^{RS})$	Profit of the LSP in platform mode (resale mode) with intelligent transformation by the LSP
$\pi_J^{PS}(\pi_J^{RS})$	Profit of the LSI in platform mode (resale mode) with intelligent transformation by the LSP
$\pi_T^{PC}(\pi_T^{RC})$	Profit of the LSP in platform mode (resale mode) with intelligent transformation by cooperation
$\pi_J^{PC}(\pi_J^{RC})$	Profit of the LSI in platform mode (resale mode) with intelligent transformation by cooperation

3.2 Equilibrium analysis

In this section, we solve and analyze the equilibrium results in six scenarios, where the solution is through the reverse recursion method. To ensure that the members of the LSSC service supply chain have positive benefits in each case, we assume that $4 - z > 0$.

PB scenario

In the PB scenario, the LSI serves as a connector between the LSP and consumers, and the LSP provides basic logistics services. At this point, the profit functions of the LSP and the LSI are:

$$\begin{cases} max\, \pi_T^{PB} = (1-u)p(a-p) \\ max\, \pi_J^{PB} = up(a-p) - A \end{cases} \tag{1}$$

In this scenario, the LSP first determines the basic logistics service price to maximize its profit, and then she pays a certain percentage of transaction fees to the LSI. We can get the following equilibrium results in the PB scenario.

$$p^{PB*} = \frac{a}{2}, q^{PB*} = \frac{a}{2}, \pi_T^{PB*} = \frac{a^2(1-u)}{4}, \pi_J^{PB*} = \frac{a^2 u}{4} - A.$$

It is easy to see from the equilibrium solution that the optimal logistics service price, the logistics service market demand, the LSI's and the LSP's profit increase with the increase of the basic logistics service market. At the same time, the profits of the LSP and the LSI decrease and increase respectively with the increase of the share ratio.

PS scenario

In the PS scenario, although the LSI proposed a joint logistics service intelligent transformation plan, but the LSP did not join the plan, at this time, the logistics service intelligent transformation cost is borne by the LSP. At this point, the profit functions of the LSP and the LSI are:

$$\begin{cases} max\, \pi_T^{PS} = (1-u)p(a-p+my) - gy^2 \\ max\, \pi_J^{PS} = up(a-p+my) - A \end{cases} \tag{2}$$

In this scenario, in addition to determining the price of logistics services, the LSP also needs to decide the intelligence level of logistics service. We can get the following equilibrium results in the PS scenario.

$$p^{PS*} = \frac{2a}{4 - z(1-u)}, q^{PS*} = \frac{am(1-u)}{4g + m^2 u - m^2}, y^{PS*} = \frac{2a}{4 - z(1-u)}, \pi_T^{PS*} = \frac{a^2(1-u)}{4 - z(1-u)}, \pi_J^{PS*} = \frac{4a^2 u}{[4 - z(1-u)]^2} - A.$$

Obviously, with the increase in the demand for basic logistics services and the efficiency of intelligent logistics transformation, the price, the market demand, the intelligence level of logistics services, and the profits of the LSI and the LSP have all increased. With the increase of the share ratio, the price, the market demand, and the intelligence level of logistics services, the profit of the LSP decreases and the profit of the LSI increases.

PC scenario

In the PC scenario, the LSP joins the joint logistics service intelligent transformation plan proposed by the LSI, and the LSI bears the proportion of the cost of the intelligent transformation as s. At this point, the profit functions of the LSP and the LSI are:

$$\begin{cases} max\, \pi_T^{PC} = (1-u)p(a-p+my) - (1-s)gy^2 \\ max\, \pi_J^{PC} = up(a-p+my) - sgy^2 - A \end{cases} \tag{3}$$

In this scenario, the LSP first determines the logistics service price p and the logistics service intelligence level y, and then the LSI decides the final cost-sharing ratio s of intelligent logistics transformation. We can get the following equilibrium results in the PC scenario.

$$p^{PC*} = \frac{a[8 - z(1-u)]}{4(4-z)}, q^{PC*} = \frac{a[8 - z(1-u)]}{4(4-z)}, y^{PC*} = \frac{am(u+1)}{8g - 2m^2},$$

$$s^{PC*}=\frac{z(1-u)^2+4(3u-1)}{4(1+u)},\pi_T^{PC*}=\frac{a^2(1-u)[8-z(1-u)]}{8(4-z)},\pi_J^{PC*}=\frac{a^2[z(1-u)^2+16u]}{16(4-z)}-A.$$

Similar to the PB scenario, with the increase in the demand for basic logistics services and the efficiency of intelligent transformation, the price, the market demand, the intelligence level of logistics services, the profits of the LSI and the LSP all increase. With the increase of the share ratio, the price, the market demand, the intelligence level of logistics services, and the profits of the LSP all decrease while the profits of the LSI increase.

RB scenario

In the RB scenario, the LSI also acts as an intermediary, and the basic logistics service is still performed by the LSP. At this point, the profit functions of the LSP and the LSI are:

$$\begin{cases}max\,\pi_T^{RB}=w(a-p)\\max\,\pi_J^{RB}=(p-w)(a-p)-A\end{cases}\tag{4}$$

In this scenario, first, the LSP decides the wholesale price, and then the LSI decides the sales price. We can get the following equilibrium results in the RB scenario.

$$p^{RB*}=\frac{a}{2},q^{RB*}=\frac{3a}{4},w^{RB*}=\frac{a}{4},\pi_T^{RB*}=\frac{a^2}{8},\pi_J^{RB*}=\frac{a^2}{16}-A.$$

It is easy to see that with the increase in the market demand for basic logistics services, the wholesale price, the sales price, the market demand, and the profits of the LSP and the LSI all increase.

RS scenario

In the RS scenario, the LSP does not participate in the joint logistics service intelligent transformation plan proposed by the LSI, and the LSI's share of the cost of the logistics service intelligent transformation is 0. At this point, the profit functions of the LSP and the LSI are:

$$\begin{cases}max\,\pi_T^{RS}=w(a-p+my)-gy^2\\max\,\pi_J^{TS}=(p-w)(a-p+my)-A\end{cases}\tag{5}$$

In this scenario, the LSP first determines the wholesale price, and then the LSP decides the sales price of the logistics service and the intelligence level. We can get the following equilibrium results in the RS scenario.

$$w^{RS*}=\frac{a}{2},p^{RS*}=\frac{a(z+6)}{8},q^{RS*}=\frac{a(2+z)}{8},y^{RS*}=\frac{am}{4g},\pi_T^{RS*}=\frac{a^2}{8},\pi_J^{RS*}=\frac{a^2(z+2)^2}{64}-A.$$

Obviously, with the increase in the demand for basic logistics services, the wholesale price, the sales price, the market demand, the level of intelligence of logistics services, the profits of the LSI and the LSP have all increased. With the increase of the efficiency level of intelligent logistics service transformation, the sales price, the market demand, and the profits of the LSI increase. The intelligence level of logistics services is positively correlated with consumers' preferences and negatively correlated with the cost coefficient of intelligent transformation.

RC scenario

In the RC scenario, the LSP participates in the intelligent logistics joint transformation plan proposed by the LSI, and the LSI shares *s* proportion of the cost of intelligent transformation. At this point, the profit functions of the LSP and the LSI are:

$$\begin{cases}max\,\pi_T^{RC}=w(a-p+my)-(1-s)gy^2\\max\,\pi_J^{RC}=(p-w)(a-p+my)-sgy^2-A\end{cases}\tag{6}$$

In this scenario, first, the LSP decides the wholesale price, then the LSP decides the sales price and cost allocation ratio of the logistics service, and finally, the LSP decides the intelligence level. We can get the following equilibrium results in the RC scenario.

$$w^{RC*}=\frac{a}{2}, p^{RC*}=\frac{a(12-z)}{4(4-z)}, q^{RC*}=\frac{a(z+4)}{4(4-z)}, y^{RC*}=\frac{am}{4g-m^2}, s=\frac{z}{4}, \pi_T^{RC*}=\frac{a^2}{8}, \pi_J^{RC*}=\frac{a^2(3z+4)}{16(4-z)}-A.$$

It is easy to see that the basic demand for logistics services and the efficiency of intelligent logistics service transformation have a similar impact on the equilibrium results in this scenario as in the RS scenario. At the same time, the influence of consumers' intelligent logistics preference and logistics service intelligent transformation cost coefficient on the intelligence level of logistics service is consistent with the impact of the RS scenario, and the proportion of intelligent logistics transformation cost sharing is positively related to the efficiency of intelligent logistics service transformation.

In the next section, we first analyze the intelligent logistics strategy choices under the platform mode and the resale mode and then compare the differences in intelligent logistics decision-making under the two modes to provide relevant management insights and implications.

4. Results and insights

4.1 Analysis under the platform mode

By comparing the equilibrium logistics service sales price, logistics service market demand, logistics service intelligence level, and profit of the LSP and the LSI under the three scenarios of the platform model, we can get Corollary 1.

Corollary 1: (1) $p^{PB*}<p^{PS*}<p^{PC*}, q^{PB*}<q^{PS*}<q^{PC*}, y^{PS*}<y^{PC*}$. (2) $\pi_T^{PB*}<\pi_T^{PS*}<\pi_T^{PC*}$if $0<z<1$ and $\pi_T^{PB*}<\pi_T^{PC*}<\pi_T^{PS*}$ if $1<z<2$; $\pi_J^{PB*}<\pi_J^{PS*}<\pi_J^{PC*}$.

To intuitively see the size of the equilibrium results in the three cases, we assume $a=1$. Combined with the numerical simulation results in Figs. 3-7, it can be seen that the comparison of the equilibrium results in the three cases under the platform mode is consistent with Corollary 1.

Corollary 1(1) shows that under the platform model, the implementation of intelligent logistics transformation will increase the price and sales of logistics services and the logistics service intelligence level is the highest during the joint logistics service intelligence transformation plan. The equilibrium price of the joint intelligent logistics service is the highest during the transformation. The reason for this phenomenon is that the LSP invests more in improving the intelligent level of logistics services, and the LSP transfers to consumers through price increases, make up for the extra costs incurred. The demand for the intelligent transformation of joint logistics services is also the highest. At this time, the demand for logistics services is simultaneously affected by the price and the intelligence level of logistics services. The intelligent transformation of joint logistics services brings a more obvious demand increase.

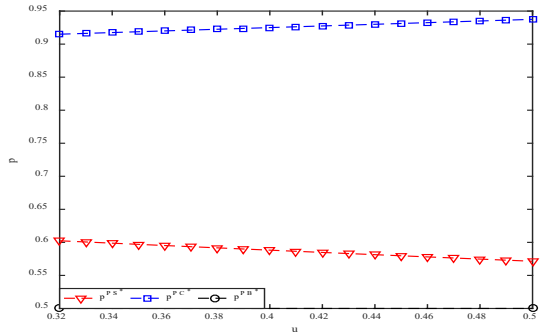

Fig. 3 Comparison of p under the platform mode

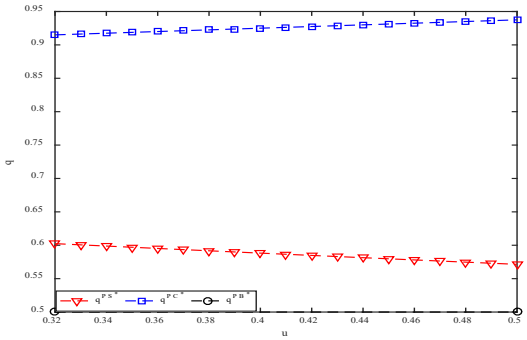

Fig. 4 Comparison of q under the platform mode

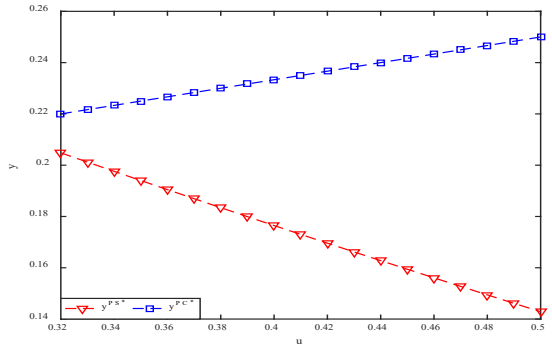

Fig. 5 Comparison of y under the platform mode

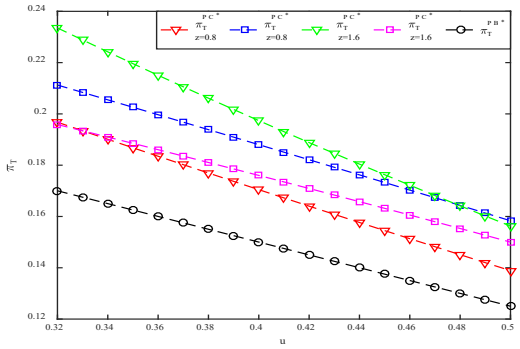

Fig. 6 Comparison of π_T under the platform mode

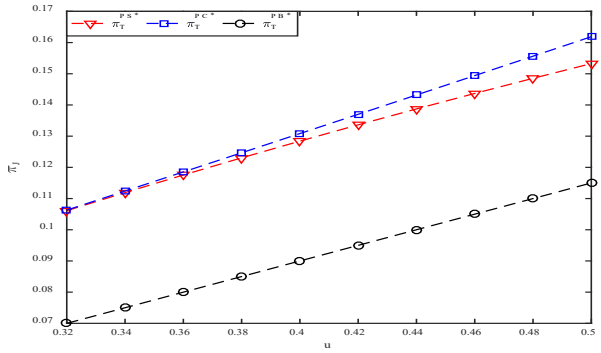

Fig. 7 Comparison of π_J under the platform mode

From Corollary 1(2), we know that the LSP participating in the LSIs' intelligent transformation will get more profit. The efficiency of logistics service intelligence transformation affects the benefit of the LSP when she adopts individual or joint logistics service intelligence. That is, when the efficiency of intelligent transformation is low, it is beneficial to the LSP when it is jointly transformed, and vice versa, it is beneficial to the LSP when it is transformed alone. For the LSI, she will get more benefits when carrying out joint intelligent transformation. If the efficiency of intelligent transformation is low, the benefit brought by the LSP's independent logistics service intelligent transformation will not be significant, and the plan to join the LSI's plan will get a part of the cost-sharing, so that the LSP's profit is higher than that of the single intelligent logistics transformation. If the efficiency of logistics service intelligence is high, although the joint transformation plan can improve the intelligence level and share a part of the cost, because of the higher share cost, the LSP is more willing to choose a separate intelligent transformation. For the LSI, choosing the joint intelligent transformation is the optimal decision. Because the LSI can grasp the different needs of consumers, and encourage the LSP to join the plan according to consumers' needs, to provide more satisfactory logistics services.

4.2 Analysis under the resale mode

Similar to the platform model, in this section, we compare the equilibrium wholesale price, the sale price, the market demand, the intelligence level, and the profit of the logistics service supply chain under the three scenarios of the resale model, we can get Corollary 2.

Corollary 2: (1) $w^{RB*} = w^{RS*} = w^{RC*}$, $p^{RB*} < p^{RS*} < p^{RC*}$, $y^{PS*} < y^{PC*}$, $q^{RB*} < q^{RS*} < q^{RC*}$.

(2) $\pi_T^{RB*} = \pi_T^{RS*} = \pi_T^{RC*}, \pi_J^{RB*} < \pi_J^{RS*} < \pi_J^{RC*}$.

Combined with the numerical simulation results in Figs. 8-11, it can be seen that the comparison relationship between the equilibrium results in the three scenarios is consistent with Corollary 2. The relationship between the wholesale price and the profit of the LSP in the three scenarios can be seen from the comparison in Table 3, and the numerical simulation is omitted.

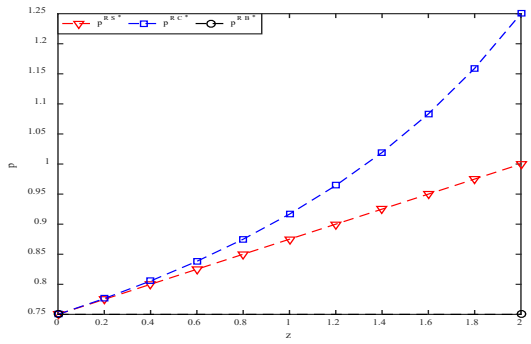

Fig. 8 Comparison of p under the resale mode

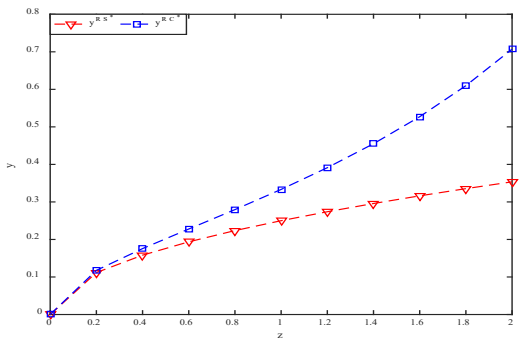

Fig. 9 Comparison of y under the resale mode

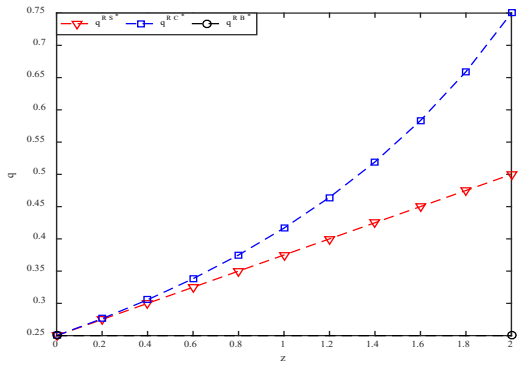

Fig. 10 Comparison of q under the platform mode

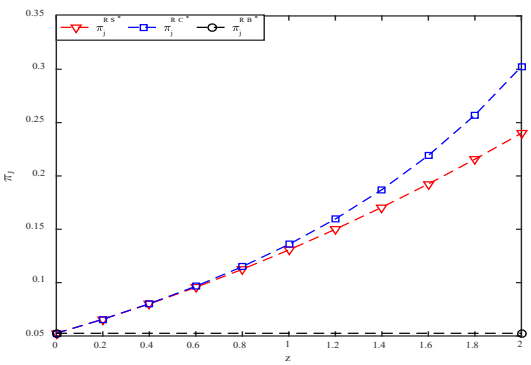

Fig. 11 Comparison of π_J under the platform mode

Corollary 2 shows that the equilibrium logistics service price, the level of logistics service intelligence, the market demand, and the LSI's profit are optimal when the LSP participates in the intelligent transformation under the resale mode, which is consistent with the platform mode. Under the resale model, the wholesale price and the LSP's profit in the three scenarios remain unchanged, which is different from the conclusion under the platform model. The main reason may be that the intelligent transformation in the resale model brings more demand but also costs more, and the cost at this time is offset by the increase in revenue brought by the increase in demand.

Therefore, the joint intelligent transformation plan of the LSI under the resale model is not very attractive to the LSP. In the resale mode, the choice of the LSP to choose independent or joint logistics service intelligent transformation depends on the efficiency of logistics service intelligent transformation. That is to say, the LSI will gain more benefits during joint intelligence transformation, that is, the LSI should actively encourage the LSP to participate in the joint intelligent transformation plan.

4.3 Comparative analysis

In this section, we will compare and analyze the equilibrium results of the LSP under different service strategies under the platform model and the resale model. We can obtain Corollary 3, Corollary 4, and Corollary 5.

Corollary 3. Comparing the equilibrium solutions of the two modes when the LSP provides basic logistics services, we can get

(1) $p^{PB*} < p^{RB*}, q^{PB*} > q^{RB*}$. (2) $\pi_T^{PB*} < \pi_T^{RB*}$ if $0 < u < \frac{1}{2}$ and $\pi_T^{PB*} > \pi_T^{RB*} \frac{1}{2} < u < 1$;
$\pi_J^{PB*} < \pi_J^{RB*}$ if $0 < u < \frac{1}{4}$ and $\pi_J^{PB*} > \pi_J^{RB*}$ if $\frac{1}{4} < u < 1$.

According to the equilibrium results in Table 3, it is easy to conclude in Corollary 3, so we omit the numerical simulation results. According to Corollary 3(1), when the LSP provides basic logistics services, the platform mode has lower logistics service prices and higher logistics service demand. The reason is that under the platform model, the price is directly determined by the LSP, which avoids the price increase by layers of pricing. According to Corollary 3(2), when the

share ratio is lower than 0.5, the LSP is more willing to adopt the platform model, and when the share ratio is less than 0.25, the LSI is more willing to adopt the resale model. At the same time, when the split ratio is between 0.25 and 0.5, the platform mode selection is the optimal strategy for both. That is to say, when providing basic logistics services, the choice of the sales model for both parties mainly depends on the size of the share ratio.

Corollary 4. Comparing the equilibrium solutions of the two modes when the logistics service provider independently carries out the intelligent transformation, we can obtain:

(1) $p^{PS*} < p^{RS*}$, $q^{PS*} > q^{RS*}$; If $0 < u < \frac{z}{4+z}$, $y^{PS*} > y^{RS*}$ and $y^{PS*} < y^{RS*}$ if $\frac{z}{4+z} < u < \frac{1}{2}$.

(2) $\pi_T^{PS*} > \pi_T^{RS*}$. When $0 < u < \frac{1}{4}$, $\pi_J^{PS*} < \pi_J^{RS*}$; and when $\frac{1}{4} < u < \frac{1}{2}$, $\pi_J^{PS*} > \pi_J^{RS*}$ if $0 < z < z_0$; $\pi_J^{PS*} < \pi_J^{RS*}$ if $z_0 < z < 2$, where $z_0 = -\frac{2(9+6u+u^2)}{3(-7+6u+u^2)}$.

Combined with the numerical simulation results in Figs. 12-16, it can be seen that the equilibrium solutions in the two modes are consistent with Corollary 4 when the logistics service provider independently transforms its logistics service intelligence.

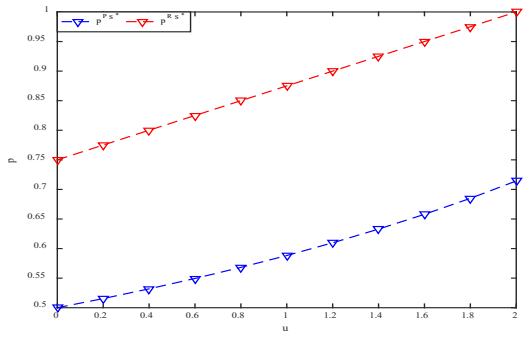

Fig. 12 Comparison of p under between PS and RS scenarios

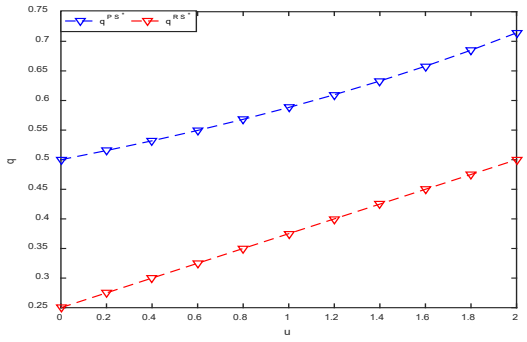

Fig. 13 Comparison of $q$between PS and RS scenarios

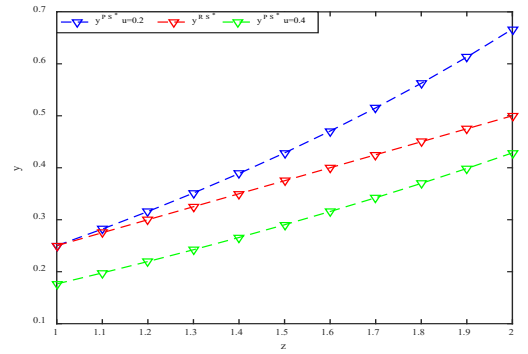

Fig.14 Comparison of y under between PS and RS scenarios

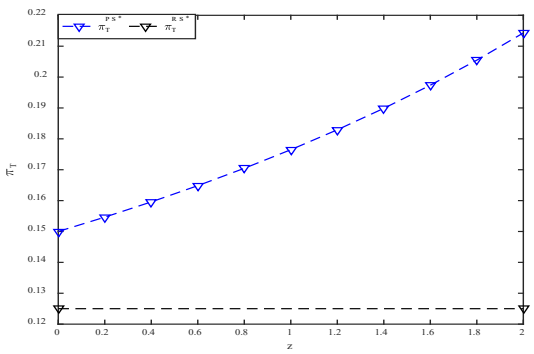

Fig. 15 Comparison of π_T between PS and RS scenarios

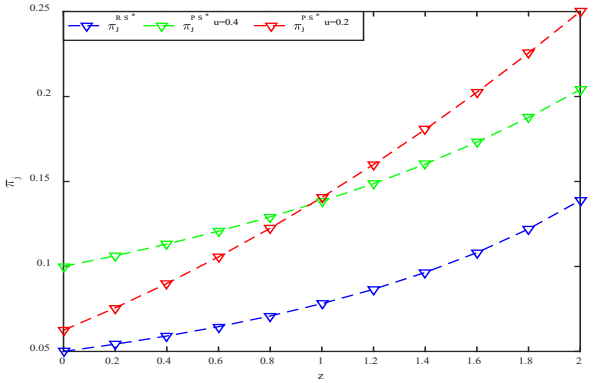

Fig. 16 Comparison of π_J between PS and RS scenarios

Corollary 4(1) shows that the logistics service price is lower in the platform mode when the LSP is independently intelligently transformed. The main reason is that there is no layer-by-layer price increase phenomenon, and the LSP will adopt measures of small profits but quick turnover to obtain more benefits. The intelligence level of logistics services under the two modes is related to the size of the share ratio. When the share ratio charged by the LSI is low, the LSP has the motivation to carry out the intelligent transformation. On the contrary, the enthusiasm of the LSP for intelligent transformation is not high, so the intelligent level of the logistics service in the platform mode is low.

Corollary 4(2) shows that the LSP can obtain more benefits by adopting the platform model when she chooses independently intelligent transformation. Although the LSP needs to pay a certain percentage of the share under the platform model, the market demand for logistics services has decreased within a certain range, but it is still higher than the resale model, and the double marginal problem caused by the increase in prices is avoided. The profit of the LSI under the two modes is related to the share ratio and the efficiency of intelligent transformation. When the share ratio is low, its income is greatly reduced, at this time, the LSI tends to choose the resale model. When the share ratio is high, if the efficiency of intelligent transformation is low, it is more advantageous for the LSI to choose the platform mode, and the platform mode is the optimal mode for both parties. If the efficiency of intelligent transformation is low, the LSI tends to choose the resale model.

Therefore, the determination of the final sales model and share ratio is affected by the market position and business negotiation strategies of both parties. At the same time, the logistics service intelligence level needs to be paid attention to. Because both parties conduct a series of commercial and technical activities to meet consumer preferences. By evaluating consumers' satisfaction with the effect of intelligent transformation, it can effectively coordinate the differences in goals between the two parties and make more scientific decisions in advance between the benefits of intelligent transformation and the losses caused by business model transformation.

Corollary 5. Comparing the equilibrium solutions of the two modes when the LSP chooses joint intelligent transformation, we can get:

(1) $y^{PC*} < y^{RC*}, p^{PC*} < p^{RC*}, q^{PC*} > q^{RC*}$. (2) $\pi_T^{PC*} > \pi_T^{RC*}$;When $\frac{1}{4} < u < \frac{1}{3}$, if $\frac{4(1-4u)}{-2-2u+u^2} < z < \frac{4(1-3u)}{1-2u+u^2}$, $\pi_J^{PC*} > \pi_J^{RC*}$ and if $\max\{\frac{4(1-3u)}{1-2u+u^2}, \frac{4(1-4u)}{-2-2u+u^2}\} < z < 2, \pi_J^{PC*} < \pi_J^{RC*}$; When $\frac{1}{3} < u < \frac{1}{2}$, if $0 < z < \frac{4(1-4u)}{-2-2u+u^2}, \pi_J^{PC*} > \pi_J^{RC*}$; and if $\frac{4(1-4u)}{-2-2u+u^2} < z < 2, \pi_J^{PC*} < \pi_J^{RC*}$.

Combined with the numerical simulation results in Figs. 17-21, it can be seen that the equilibrium solution results in the two modes are consistent with Corollary 5 when the LSP chooses joint intelligent transformation.

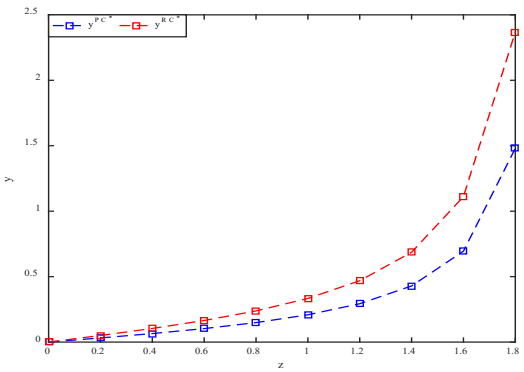

Fig. 17 Comparison of y under between PC and RC scenarios

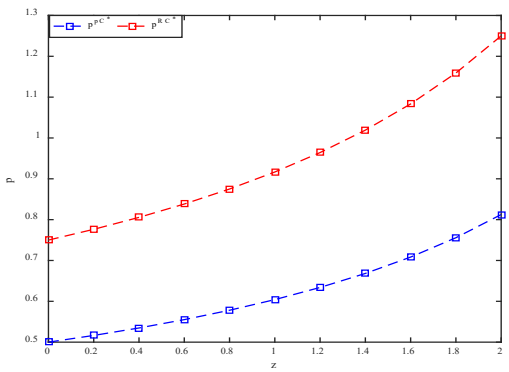

Fig. 18 Comparison of p between PC and RC scenarios

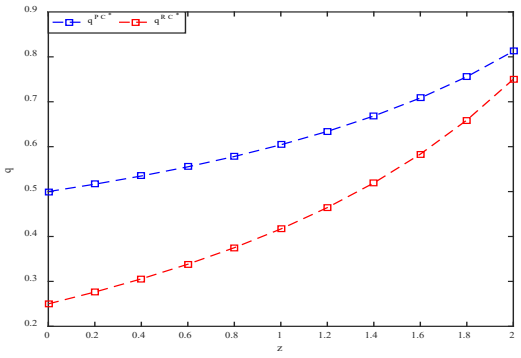

Fig. 19 Comparison of q under between PC and RC scenarios

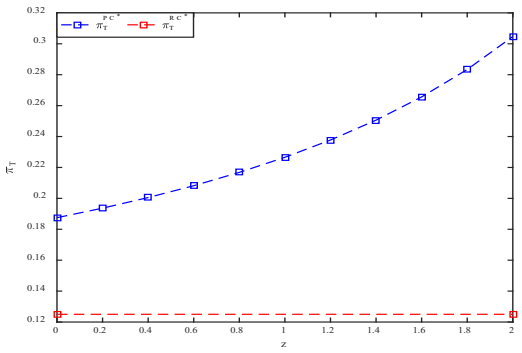

Fig. 20 Comparison of π_T between PC and RC scenarios

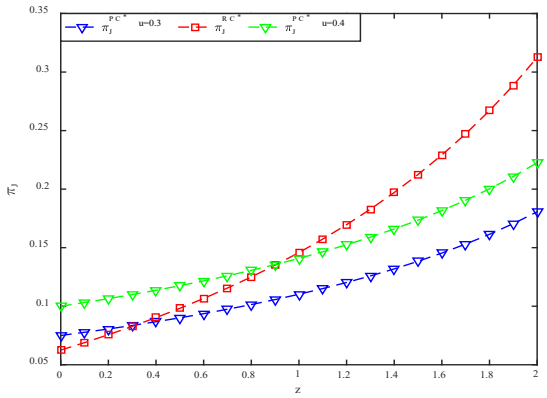

Fig. 21 Comparison of π_J under between PC and RC scenarios

Corollary 5(1) shows that when the LSP chooses joint intelligent transformation, the logistics service intelligence level under the resale mode is higher. On the one hand, it is because the cost of intelligent transformation is shared under the resale model, and on the other hand, the LSP can obtain the benefits of intelligent transformation of intelligent logistics services. In the process of intelligent transformation, the additional cost of logistics service providers in the resale mode is transferred to the LSI through wholesale prices, so the LSI will appropriately increase the sale price.

Corollary 5(2) shows that when the LSP chooses to participate in joint intelligent transformation, she will gain more benefits under the platform model. Since the double marginal problem of cooperation between the two parties in the platform model is eliminated, the resale model will make the price of logistics services too high, resulting in a decrease in the demand for the entire logistics service market. For the LSI, the profit of the LSI in the two modes depends on the proportion of shares and the efficiency of intelligent logistics service transformation. When the efficiency of intelligent transformation is low and the share ratio is not too low, the profit of the LSI in the platform mode is higher than that in the resale mode. Conversely, the LSI will gain more benefits under the resale model. Therefore, when the LSP chooses intelligent transformation, the LSI will decide which mode to adopt according to the efficiency of the logistics service transformation and the share ratio obtained.

5. Conclusion

5.1 Key findings and managerial implications

In the context of intelligent logistics transformation, this paper discussed whether the LSP should transform alone or participate in the joint transformation of the LSI's plan, and compared the difference of equilibrium results under the platform model and the resale model. We got the following conclusions.

First, when providing basic logistics services, the platform model has lower prices and a higher sales volume, and the profits of the LSP and the LSI depend on the size of the share ratio. Meanwhile, choosing the intelligent transformation can improve the benefit of the entire supply chain. Second, when the LSP chooses joint intelligent transformation, she can obtain more market demand with higher intelligent logistics service level, and at the same time, the LSI can obtain more profits. For the LSP, under the platform model, the LSP can obtain higher profit, while under the resale model, regardless of whether she participates in the joint transformation, there is no difference in her profit. Third, for the LSP, when participating in the joint intelligent transformation, the level of intelligent logistics service in the resale mode is higher than that in the platform mode; when the LSP independently transforms its logistics service intelligently, the share ratio will affect the level of intelligent logistics service under the two modes. Whether the LSP conducts independent or joint intelligent transformation, more profits can be obtained in the agency mode. Finally, for the LSI, no matter which intelligent transformation method the LSP chooses, the share ratio and the level of logistics service intelligence will affect the size of her profit under the two modes.

Based on the research in this paper, we can draw the following management insights. First, the intelligent transformation of logistics services is necessary for LSP, because more profit can be obtained with a higher level of logistics service intelligence.

Secondly, the LSP should actively participate in joint intelligent transformation. Although there is no difference in profit whether or not to participate in the joint intelligent transformation under the resale mode, the LSP can request compensation from other aspects to ensure the overall intelligence level of logistics services and its own profit. Finally, in the platform mode, the LSI should consider the intelligent transformation willingness of the LSI when adopting joint intelligent transformation. When there is a deviation in the preferences of both parties, it is necessary to balance the effects brought by the intelligent transformation and the risks brought by the choice of sales models.

5.2 Limitations and future research directions

In addition, there are still some limitations in this study, which can be used as a direction for further attention in the future. First, this paper considers cost sharing in the joint intelligent transformation, and future research is worthy of further research on other forms of compensation. Second, we assume that the information of the LSI and the LSP is completely symmetrical, and it will be necessary to consider asymmetric information for intelligent transformation. Finally, we assume that the impact of intelligent transformation on demand is certain, and the conclusions drawn from studying the impact of intelligent transformation on other forms of demand may be more interesting.

Acknowledgement

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Appendix A

Proof of Corollary 1

(1) $p^{PC*}-p^{PS*}=\frac{az\left(-4-2u(-6+z)+z+u^2z\right)}{4(4-z)(4+(-1+u)z)}$, because $4-z>0$ and $4+(-1+u)z>0$, then it only needs to satisfy that $-4-2u(-6+z)+z+u^2z$ is positive，we can get $p^{PC*}>p^{PS*}$. We know that $s>0$ when $\frac{-6-2\sqrt{9-2z}+z}{z}<u<0.5$， then $-4-2u(-6+z)+z+u^2z$ is always greater than 0，we can get $p^{PC*}>p^{PS*}$. At the same time $p^{PS*}-p^{PB*}=\frac{az(1-u)}{8-2z(1-u)}>0$，we can get $p^{PB*}<p^{PS*}<p^{PC*}$. Proof relationship between $q^{PB*}, q^{PS*}$and q^{PC*}, and proof of relationship between $y^{PS*}$and y^{PC*} is similar to the proof of the relationship between p^{PB*}, p^{PS*} and p^{PC*}, here we omit.

(2)$\pi_T^{PC*}-\pi_T^{PS*}=\frac{a\left(-4z+12uz+z^2-2uz^2+u^2z^2\right)}{4(4-z)(4-z+uz)}$， because $4-z>0$ and $4+(-1+u)z>0$，then it only needs to satisfy that $-4z+12uz+z^2-2uz^2+u^2z^2$ is positive，we can get $\pi_T^{PC*}>\pi_T^{PS*}$. Solve the quadratic equation of $-4z+12uz+z^2-2uz^2+u^2z^2=0$ with respect to u，we can get $\frac{-6-2\sqrt{9-2z}+z}{z}<u<0.5$，at this time $-4z+12uz+z^2-2uz^2+u^2z^2$ is always greater than 0，we can get，so$\pi_T^{PC*}>\pi_T^{PS*}$. Meanwhile, $\pi_T^{PS*}-\pi_T^{PB*}=\frac{a(1-u)z}{2(4-(1-u)z}>0$，we can get $\pi_T^{PB*}<\pi_T^{PS*}<\pi_T^{PC*}$. Proof relationship between $\pi_J^{PB*}, \pi_J^{PC*}$and π_J^{PS*} is similar to the proof of the relationship between π_T^{PB*}, π_T^{PS*} and π_T^{PC*}, here we omit.

Proof of Corollary 2.

The proof of Corollary 2 is similar to the proof of Corollary 1, here we omit.

Proof of Corollary 3.

The proof of Corollary 3 is similar to the proof of Corollary 1, here we omit.

Proof of Corollary 4.

The proof of Corollary 4 is similar to the proof of Corollary 1, here we omit.

Proof of Corollary 5.

The proof of Corollary 5 is similar to the proof of Corollary 1, here we omit.