Selection of logistics service modes in e-commerce based on multi-oligopolies Cournot competition

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Abstract: This paper focuses on the selection of e-commerce logistics service modes that is becoming more and more prominent as its importance. The current researches are mainly limited by using the empirical method but rarely considering the multi-oligopolies competition and comparison among modes. Four modes are modelled in this paper based on multi-oligopolies Cournot competition theory. The results show that the improvement of logistics service management and technological progress are the basis, the marginal service cost is the most important, then the transaction cost and the scale effect in the mode selection. When the logistics service ability is given, the mode of opened platform provides to online stores (PO) is an advantage strategy for e-commerce platform and common online stores. The mode of opened 3PL providers provide to online stores (TO) is an advantageous strategy with competitive price for opened platform and is more attractive to small online stores.

Keywords: e-commerce; electronic commerce; logistics service mode; mode selection; multi-oligopolies Cournot competition.

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1 Introduction

Since venturing into the 21st century, with the popularity of internet, smart terminal equipment, improvement of consumption desire and consumption capability of residents, e-commerce is fast developed and as a method of buying or selling via telecommunications and computer networks, has redefined and changed the ways how people live and how business is conducted (Ramanathan, 2010; Wang and Liu, 2015). Although popular in most developed countries, it exists only about 15 years in developing countries like China, is growing at a considerable rate (He, 2010). For example, during 2008–2012, Chinese online shopping market size ascended from £12.82 billion to £130.30 billion (PRNewswire, 2014). In 2014, China business-to-consumer (B2C) market soared 68.7% and C2C market increased 35.2% comparing to 2013 (iResearch, 2015).

The booming of e-commerce promotes the development of logistics industry, especially the expansion of express industry (Jiang and Prater, 2002). The importance of logistics service to the operation and development of e-commerce is increasingly prominent. Although e-commerce and logistics are two areas over researched during the past decades in developed countries, there are still few empirical studies in developed countries that explore and how logistics services and infrastructure impact on the B2C markets in China (Zhou, 2013). High level logistics service including storage, order selection, transportation, etc. is helpful to improve the customer satisfaction and loyalty, whether to choose self-operating or subcontracting service mode.

The e-commerce modes are diverse like B2B, B2C, C2C, etc., but it can be summarised into two types in B2C mode: opened platform e-commerce and integrated e-commerce (Kwark et al., 2014). An opened platform would not trade anything by itself but provide e-commerce service to online stores and the service objects of logistics service are online stores. An integrated platform will make self-operated business and the service object of logistics service is platform. There are many platforms which combined above two types such as self-operating mode of Tmall Supermarket (https://chaoshi.tmall.com) and JD (https://www.jd.com) with plenty of external online stores (Xiao et al., 2012). Similarly, the logistics service corresponding to e-commerce can be sourced from two places: platform provided (PP) (self-operation) and third-party logistics (3PL) provider.

Therefore, there are four types of possible service mode: opened platform provides to online stores (PO), opened 3PL providers provide to online stores (TO), integrated PP and integrated 3PL provider (TP) as shown in Table 1 (Lan and Wu, 2010; Alkhatib et al., 2015).

Table 1 Logistics service modes of e-commerce

Logistics service source	*Formats of e-commerce/service object*	
	Opened/online stores (O)	*Integrated/platform (P)*
Platform provided (P)	Mode I: (PO) Opened platform provides to online stores	Mode III: (PP) Integrated platform provided
3PL provider (T)	Mode II: (TO) Opened 3PL providers provide to online stores	Mode IV: (TP) Integrated 3PL provider

However, the relationship between different logistics service modes and e-commerce operation effect has never been clarified (Ramanathan, 2010). This is rather bad for the effective strategic decision of e-commerce enterprises and is urgent demand to make a thorough illustration. There are many reasons which caused the difference of logistics service performances. Different marginal service cost is the most fundamental characterisation to logistics service level and an important factor affecting the service performance (Yuan et al., 2014). 3PL provider has the professional advantage to save the service costs. Sharing and learning of logistics management capability is helpful to reduce such differences. Besides, the 3PL service will increase the cost and welfare loss due to ‘double marginalisation effect’ (Spengler, 1950). On the one hand, the logistics service for e-commerce has been regarded as a ‘back-bone’ role, on the other hand, enterprises are facing with many contradictions and conflicts to choose logistics mode for e-commerce. So, the logistics service in e-commerce has become a hot topic and difficult topic in this field and has been attracted close attention of researchers (Delfmann et al., 2002).

However, up to now, main research work is still focused on the logistics operation and its optimisation. Most research work is mostly limited to the case study and empirical field. Individual mechanism research on service mode selection is rare and some limited work is focusing on the efficiency analysis to single service mode, but not modes trade-off. ‘Exemplifying theory’ (Rasmusen, 2006) is adopted in this paper and in some of the typical examples; we found a simple assumption which is necessary to get an interesting conclusion with the modelling idea. These modelling ideas normally can provide the answers for some specific questions and depict more profound mechanism. As Fisher’s (1989) research, this modelling method does not tell us what is bound to happen, but tells us what can happen. The modelling process is to establish a proposition of ‘If……, then……’, usually it is started by a vague idea, then in a simple way, the idea will be formally modelled. Under certain conditions, this model is used to provide more accurate theorems, the proof of theorems will enable modellers have a further understanding for that idea, which enables modellers beyond the logic of mathematics to rethink them, finally it is formed a more in-depth understanding for the problem. If such propositions are used, their logical premises and conclusions are needed to go through or lax or rigorous empirical tests (Rasmusen, 2006).

The e-commerce logistics service is in a period of rapid development, the influence factors are not obvious and the industrial form needs to be finalised. Therefore, it is too early to form any definitive conclusion. However, from the different perspective, exploring the possible law of development under certain conditions is a more realistic choice. The background of such a problem is the best scene using 'exemplifying theory'. Firstly, the mechanism model for four types of representative e-commerce logistics service mode are established based on the common assumption and variables system, so that it will be rational to make the comparative static analysis between various modes. Secondly, the platform economy is a typical network economy with the obvious network effect and the significant scale effect (Rochet and Tirole, 2003). The competition advantage is influenced by both market scale and number change of online stores, therefore, multi-oligopoly but not duopoly Cournot game model is adopted during modelling. Thirdly, previous studies showing that there are many factors, which will affect the e-commerce performance, for example, product, user type, transportation, warehousing technology, market scale, management capacity, service quality, location and even industry regulation and so on, but most of these factors will not influence the performance with relative difference (Delfmann et al., 2002; Yuan et al., 2014; Ghezzi et al., 2012; Ramanathan, 2010; Zailani et al., 2017; Huang and Yin, 2014). Therefore, the relationship between customer experience and the logistics service level has been confirmed by a large number of empirical studies. Customer satisfaction is taken as the core in this paper while considering few correlation factors including marginal service cost, transaction cost, service market scale and the number of online stores which will obviously impact the service mode (Ghezzi et al., 2012).

The contribution of this paper is that the internal mechanism of different types of e-commerce platform for selection of logistics service modes is given under the different decision objectives. Build the models and comparative static analysis for four main logistics service modes and try to explain the influence of service level, service scale, service cost and service price and the other factors on the selection of e-commerce logistics service mode.

The other parts of this paper are structured as follows: related reference literatures are described in Section 2, exemplifying modelling of four types of modes are provided in Section 3, equilibrium results of four types of modes are discussed in Section 4, comparison and analysis to four types of modes are made in Section 5 and conclusions from the research achievements are discussed and summarised in Section 6.

2 Literature review

Current literature on e-commerce logistics services can be classified into three categories. The first is related to the research on the service strategy and service improvement of logistics, the second is related to the research on logistics service mode and the last is about the choice of research methods.

2.1 The research on the service strategy and service improvement of logistics

It has been proved by large number of studies that logistics services play a significant role in the development of e-commerce and more and more enterprises begin to pay attention to logistics service strategy. 3PL services are being used by more and more e-commerce enterprises (Marasco, 2008). Good logistics services, as one part of strategy integration for supply chain, can promote the customer satisfaction, impose direct and positive effect on e-commerce marketing performance and indirectly improve the financial performance (Green et al., 2008). There is a positive relationship between logistics service level and e-commerce performance but it is difficult to determine the relationship between the selection self-operation or 3PL service mode and enterprise performance. The effective coordination of related parties is important to e-commerce logistics service (Cho et al., 2008). Delfmann et al. (2002) analysed the changes of the 3PL service provider caused by the e-commerce environment and suggested that the service providers shall implement the flexible service capability and market service coverage strategy. Bask (2012) summarised present studies on e-commerce logistics services into seven types of main topics in which the most attractive one is correlation between logistics and retail strategy, the strategy and structure of logistics and customer preference. Ngai and Gunasekaran (2003) found that many e-commerce companies choose 3PL services in order to reduce the operation cost, focus on the core business and improve customer satisfaction in the study of cross-border e-commerce.

Cost and service are often the most important factors to evaluate a logistics partner. Gronroos (1996) found it has been proved in empirical research that the quality of service which is taken as the impact variables of 3PL and 3PL success has a great impact on the 3PL success. Through questionnaire and interviews with more than 300 companies for consumer goods in Europe, Juriado and Wilding (2004) showed that the most important factor in logistics outsourcing strategy is the service related business. Dumrongsiri et al. (2008) found that the price and service are the determinant factors of consumer choice for shopping. Weltevreden (2008) analysed two types of collection-and-delivery points (for short, CDPs) and their advantages and disadvantages respectively in details and found that CDPs with someone on duty can provide better customer experience because the service is included in more payment choices, less requirement for operation knowledge and more flexible package size and so on. Present studies reflect the characteristics of the development of e-commerce logistics services: the complexity of conventional storage and transportation management is lower, but with less effect on performance. By contrast, the importance of customer experience, service level, resource integration capabilities and service scale are becoming more and more prominent.

2.2 The research on logistics service mode

There is a lot of studies on logistics service models and most of them focus on the choice of service outsourcing. Through the study of Malaysia logistics outsourcing practice, Zailani et al. (2017) summarise the basic modes and the influence factors of logistics outsourcing and discover that the lack of human resources, the lack of service capacity and the uncertainty of transaction level are the important factors affecting the outsourcing decision at current. Ghezzi et al. (2012) analysed the logistics problem of enterprises and the choice of logistics strategy through the logistics operation of 28 leading B2C e-commerce companies in Italy by the method of case study from two dimensions of cost enabler and service enabler and established the credible matching relation. With the increasing complexity of logistics problems, logistics strategy has gradually changed from supplier full managed to merchant managed inventory and full in-source managed. It seems that the logistics problems are more complex, so more joint cooperation of interested parties will be required. Wu et al. (2015) studied the effect of logistics service level on the supply chain performance in different dominant modes. Alkhatib et al. (2015) studied the evolutionary process of logistics service provider and found the previous studies on logistics service outsourcing are based on questionnaires and empirical methods, but lack of comparative research on the mechanism of cost, service relationship and different logistics modes.

2.3 The choice of research methods

The research on the choice of e-commerce logistics service mode mainly adopts the theory and method of two-sided market. Initially, Rochet and Tirole (2003) established the basic theoretical framework of two-sided market by analysing the behaviour characteristics of banks and customers of the credit card market; Armstrong (2006) modelled and analysed the market phenomenon with platform characteristics such as the shopping malls and newspapers. Two-sided market theoretic-basis is also established in above two literatures. The research of Seamans and Zhu (2014) is based on the competition between subscription and advertising and that between sponsorship platforms and a full advertising and sponsorship platform and they explored the issue on the market entry of differentiated platform. Niculescu and Wu (2014) studied the different business modes for selling software products, such as free value-added models and so on. At present, a large amount of literatures have been accumulated. All of these studies assumed that the competition platform only provides the same basic service to customers and research framework of Hotelling model is used by most of the scholars. The former assumption is helpful to simplify the problem and the nature of problem will not be affected. However, when the service is characterised with significant economic scale, the latter assumption will be lack of characterisation capabilities because no consideration is given to the dynamic nature of market scale. When the e-commerce enterprises want to choose the logistics mode, a major decision basis will be the trend of service scale (Delfmann et al., 2002), therefore, the Hotelling normal form will be faced with insurmountable difficulties, but on the contrary, the research framework of Cournot model is better from this perspective.

3 Hypotheses and models

Based on the research conclusions of Huang and Yin (2014) for B2C logistics mode selection practice and the method by Johnson and Myatt (2006) and Tirole (1988) for multiproduct Cournot competition, a series of sequential game models are established with logistics service level (quality of service), service scale, service cost and service price as variables and a comparative static analysis is carried out.

3.1 Hypotheses

3.1.1 Hypothesis 1

There is one e-commerce platform for B2C market with integrated market scale of 1. There are online stores selling the homogeneous products on the market, so the market is symmetrical and all online stores are exactly the same. Marketing activities of product include two parts: online sales and logistics services.

3.1.2 Hypothesis 2

Assume that for online sales, each type of product implements same marketing strategies and the marginal cost of the product is constant, so it is standardised to 0. The platform will charge the commission at rate of θ, $\theta \in (0, 1)$. It is assumed that all services related to the platform and customer experience are achieved by logistics services.

The sale volume of i^{th} online store is q_i on the platform and the total volume of platform is $\sum_{i=1}^{n} q_i, i \in [1, n] \in Z^+$.

Because it is relative to integrated market scale, the supply capacity of a single online store is limited permanently, it is assumed that Cournot competition among those online stores (Tirole, 1988), product price $p_i(Q, s_i)$ is affect by the total demand Q and logistics customer satisfaction s_i, $\frac{\partial p_i}{\partial Q}(Q, s_i) < 0$ and $\frac{\partial p_i}{\partial s_i}(Q, s_i) > 0$. For the sake of simplicity, assume the inverse demand function is $p_i = 1 - \sum_{i=1}^{n} q_i + s_i$. At this moment, the market is cleared.

3.1.3 Hypothesis 3

Services of logistics can be simply divided into two parts: one is distribution transportation and the other is information and customer service. Logistics service sources from platform provides (P) and 3PL (T, third-party logistics); service object from online stores (O) and platform (P).

Assuming that any level service requirements can be satisfied no matter which mode is adopted, the total cost of service is $c_i^s(s_i), c_i^{s'}(s_i) > 0$ and $c_i^{s''}(s_i) > 0$. Therefore, quadratic form cost function $c_i^s(s_i) = \frac{1}{2}\kappa s_i^2$ is selected and κ is the sensitive coefficient of service cost *Vs* service satisfaction. Assume that the unit cost of distribution transportation is constant and standardised to 0.

Most of the e-commerce platforms have only started logistics business in recent years and are supposed to expand investment in infrastructure construction, therefore platforms provide logistics services more benefits with obvious scale merit. If the platform provides the logistics services, the fixed investment is F. The online stores must pay unit service cost w_i^S to the platform.

Comparing with platform provides logistics services, the development of 3PL enterprises is relatively mature. As long as it is profitable, the 3PL enterprises have sufficient market demand and full capacity to provide services to online stores for their logistics needs $\bar{Q} > Q$. The logistics service has significant scale benefit. If the 3PL services are adopted, then the online stores must pay unit service cost w_i^T to them.

3.2 Models

Assume that all market participants are risk neutral, while the market information is complete. The technology and management of e-commerce logistics service are the common knowledge of service self-operator, 3PL providers and users. The profit level of the participants is determined by market demand, business model, pricing and cost structure. According to the hypothesis, the inverse demand function of the oligopolistic competition in e-commerce market is

$$p_i = 1 - \sum_{i=1}^{n} q_i + s_i \tag{1}$$

Four possible logistics service modes, as noted above, are presented as follows.

3.2.1 Platform provides to online stores (PO)

Platform constructs and operates the logistics service capabilities by itself, provides chargeable service to online stores, but commission has already been included in the service fees, so no repeat commission will be charged. Platform does not operate e-commerce business but provided logistics service which is not considered as optimistic in the early development of electronic commerce. However, this mode is becoming one of the mainstream models at present. An important adopter of this mode is 'Cainiao Network' (https://yz.cainiao.com) of Alibaba (https://www.1688.com). 'Kangaroo Network' (http://xylv88.com) is one of the core competencies of Meituan (http://www.meituan.com) and become a typical mode of platform provides. Platform provides the unified customer service and the service level is same for all online stores, $s_i = s$ and $w_i^S = w_S$ in PO mode:

- profits online store is:

$$\pi_i = p_i q_i - w_i^S q_i \tag{2}$$

- profit of the platform:

$$\pi = \sum_{i=1}^{n} w_i^S q_i + c_i^s - F. \tag{3}$$

3.2.2 3PL providers provide to online store (TO)

3PL providers provide service to online store and the service scales of each logistics provider is $m \in [1, n]$ online store. This is the most common e-commerce logistics service mode and almost every platform uses it in certain degree. The most representative ones among them are Taobao (https://www.taobao.com) and Tmall, but Amazon (https://www.amazon.cn), Meituan, etc. are also on the list. Even JD, as a self-operation logistics banner, a lot of online stores which also use this mode in this platform. In general, the online stores will mark the logistics service fees in order and included it in the cost of shopping, so no extra fee will be charged in TO mode:

- profit of online store is:

$$\pi_i = (1-\theta)\left(p_i - w_i^T\right)q_i \tag{4}$$

- profit of platform:

$$\pi = \sum\nolimits_{i=1}^{n} \theta\left(p_i - w_i^T\right)q_i \tag{5}$$

- profit of logistics provider:

$$r = w_i^T\left(mq_i\right) - c_i^s. \tag{6}$$

3.2.3 Platform integrated self-operation (PP)

Platform self-operates e-commerce business, organised and supposed the logistics service capabilities by itself. In the early development of e-commerce, the mode is 'asset-heavy' and was often being criticised by people. With the popularity of e-commerce and the increasing demand of customer experience to e-commerce, this mode has been widely sought due to the better service experience. The part of self-operates of JD and Amazon are the most representatives in this mode. $p_i = p$ and $q_i = Q$ in PP mode. The logistics service and service level of the platform is unique $s_i = s$. So, profit of platform namely online stores is:

$$\pi = pQ - c_i^s - F. \tag{7}$$

3.2.4 Integrated platform 3PL (TP)

Platform self-operates e-commerce and authorises the 3PL providers to provide logistics service. This mode is often the basic choice of integrated self-operation platform in early development stage, however, after platform reaches a certain scale and business mode is stabilised, platform logistics service will be diversified. 3PL are continuous limited in partial service link, variety and area (Huang and Yin, 2014). The mode has been adopted by many other e-commerce platforms, for example, Amazon and Dangdang. $p_i = p$ and $q_i = Q$ in TP mode. Service level of logistics service is unique $s_i = s$ and $w_T^S = w_T$. So:

- profit of platform is:

$$\pi = \left(p - w_T\right)Q \tag{8}$$

- profit of logistics provider:

$$r = w_T Q - c_i^s. \tag{9}$$

In the different service mode, timing of the game:

1. 3PL provider determines the logistics service level s_i.
2. 3PL provider determines the logistics service price $w_i^T\,(w_i^S)$.
3. Online stores (or platform) determine the optimum sales volume q_i and corresponding price pi in order to satisfy the market demand which is determined by p_i, s_i.

Use the backward induction to solve the sub game perfect Nash equilibrium.

4 Equilibrium analyses

4.1 Mode I: PO

In PO mode, the platform provides the unified customer service, the same service level and pricing for all online stores, $s_i = s$ and $w_i^S = w_S$. Platform will only charge service fees from online stores and commission has been included in the service fees. According to formulae (1) and (3), while in a competitive equilibrium, we can get Lemma 1 as follows.

Lemma 1: In the mode with service provided by platform to all online stores, when $\frac{n}{2(n+1)} < \kappa,$ customer satisfaction is $s^{1*} = \frac{n}{2\kappa(n+1)-n},$ equilibrium price of service is $w_S^{1*} = \frac{\kappa(n+1)}{2\kappa(n+1)-n},$ equilibrium price of product is $p^{1*} = \frac{(n+2)\kappa}{2\kappa(n+1)-n},$ sales volume of an online store is $q_i^{1*} = \frac{\kappa}{2\kappa(n+1)-n},$ profit of an online store is $\pi_i^{1*} = \frac{\kappa^2}{\left[2\kappa(n+1)-n\right]^2},$ total sales volume of platform is $Q^{1*} = \frac{n\kappa}{2\kappa(n+1)-n}$ and profit of platform is $\pi^{1*} = \frac{n\kappa}{2\left[2\kappa(n+1)-n\right]} - F.$

See Appendix for the proof for Lemma 1.

It is easy to know by Lemma 1, $\frac{dq_i^{1*}}{d\kappa} < 0, \frac{d\pi_i^{1*}}{d\kappa} < 0, \frac{dp_i^{1*}}{d\kappa} < 0, \frac{ds^{1*}}{d\kappa} < 0,$ that is, sales volume, profit, product price and customer satisfaction of online stores have the negative correlation with service cost. $\frac{ds^{1*}}{dn} = \frac{2\kappa}{\left[2\kappa(n+1)-n\right]^2} > 0,$ that is, customer satisfaction has the positive correlation with online stores number. This result shows that the more online stores there are, the more intense the market competition will be and the more perfect market competition tends to be, the higher platform positivity service level will be. According to $\frac{dp_i^{1*}}{dn} = \frac{\kappa(1-2\kappa)}{\left[2\kappa(n+1)-n\right]^2}, \frac{d\pi_i^{1*}}{dn} = \frac{2\kappa^2(1-2\kappa)}{\left[2\kappa(n+1)-n\right]^3}, \frac{dp^{1*}}{dn} = \frac{2\kappa(1-\kappa)}{\left[2\kappa(n+1)-n\right]^2},$ when $\frac{n}{2(n+1)} < \kappa < \frac{1}{2},$ there is $\frac{dq_i^{1*}}{dn} > 0, \frac{d\pi_i^{1*}}{dn} > 0.$ When $\frac{n}{2(n+1)} < \kappa < 1,$ there is $\frac{dp^{1*}}{dn} > 0,$ that is, sales volume, profit and product price of online stores have the positive correlation with online stores number. When $\frac{1}{2} < \kappa,$ there is $\frac{dq_i^{1*}}{dn} < 0, \frac{d\pi_i^{1*}}{dn} > 0.$ When

$1 < \kappa$, there is $\frac{dp_i^{1*}}{dn} < 0,$ sales volume, profit and product price of online stores have the negative correlation with online stores number. This result shows that although increased service cost will reduce the sales volume, profit of online stores and product price, but when service cost is lower, increasing of online stores number will improve product price, sales volume and profit. Therefore, there is Inference 1 as follows.

Inference 1: In the mode with service provided by platform, if the service cost is higher, the service level of platform will be lower, the sales volume and profit of online stores will be less as well as the product price will be lower. When online stores number is increased, platform will be promoted to improve service. When service cost is lower, it will result in the synchronous growth of sales volume, profit and product price in pace with online stores number.

In addition, $\frac{dw_S^{1*}}{d\kappa} < 0, \frac{dQ^{1*}}{d\kappa} < 0, \frac{d\pi^{1*}}{d\kappa} < 0,$ that is, service price, market scale and profit of platform have negative correlation with service cost. Because of $\frac{dw_S^{1*}}{dn} < 0, \frac{dQ^{1*}}{dn} < 0,$ $\frac{d\pi^{1*}}{dn} < 0,$ that is, increased online stores number will improve the service price, market scale and profit of platform. According to $\pi^{1*} = \frac{n\kappa}{2\left[2\kappa(n+1)-n\right]} - F$ and with given F, the participation constraint of the platform to provide logistics services is $2 + \frac{2}{n} - \frac{1}{\kappa} \le \frac{1}{F}.$ This can be satisfied only when the value of is n large enough and the value of κ is small enough. With increased F, n must be increased and κ must be decreased. Comparing this result with Inference 1, we will find that when the value of n is large enough and value of κ is small enough, platform provides logistics service will promote platform and online stores to improve the revenue. Because κ is the industry level of logistics management, F is the industry level of logistics technology and the management and technology level of logistics industry are improved. It is beneficial to the implementation of platform provides logistics service modes. So, there is Inference 2 as follows.

Inference 2: In the mode of PO, the higher customer service cost is, the less service price, market scale and profit will be. Increased online stores number will improve the service price, market scale and profit of platform. Improved management and technology level of logistics will bring mutual benefit to both platform and online stores, even more benefit to the implementation of PO mode.

4.2 Mode II: TO

In TO mode, 3PL enterprises provide the service to online stores and the service scale of one 3PL is mq_i, $m \in [1, n]$ online stores. Same as mode I, the market is symmetric structure $w_i^T = w_T$, $s_i = s$ and $Q = nq_i$. According to formulae (1), (4), (5) and (6), while in a competitive equilibrium, we can get Lemma 2 as follows.

Lemma 2: In the mode with 3PL providing logistics service to all of online stores, if service scale of each logistics provider is m online stores, when $\frac{n}{2(n+1)} < \kappa,$ customer satisfaction is $s^{2*} = \frac{m}{2\kappa(n+1)-m},$ equilibrium price of service is $w_T^{2*} = \frac{\kappa(n+1)}{2\kappa(n+1)-m},$ equilibrium price of product is $p^{2*} = \frac{\kappa(n+2)}{2\kappa(n+1)-m},$ sales volume of an online store is $q_i^{2*} = \frac{\kappa}{2\kappa(n+1)-m},$ profit of an online store is $\pi_i^{2*} = \frac{(1-\theta)\kappa^2}{\left[2\kappa(n+1)-m\right]^2},$ total sales volume of platform is $Q^{2*} = \frac{n\kappa}{2\kappa(n+1)-m},$ profit of platform is $\pi^{2*} = \frac{n\theta\kappa^2}{\left[2\kappa(n+1)-m\right]^2}$ and profit of logistics providers is $r^{2*} = \frac{m\kappa}{2\left[2\kappa(n+1)-m\right]}.$

See Appendix for the proof for Lemma 2.

It is easy to know by Lemma 2, there are $\frac{dw_T^{2*}}{d\kappa} < 0, \frac{dr^{2*}}{d\kappa} < 0, \frac{ds^{2*}}{d\kappa} < 0,$ that is, service price, profit and service level of logistics providers have the negative correlation with service cost. According to $\frac{m}{2(n+1)} < \kappa,$ there is $\frac{dw_T^{2*}(n)}{dn} < 0, \frac{dr^{2*}(n)}{dn} < 0, \frac{ds^{2*}(n)}{dn} < 0,$ $\frac{dw_T^{2*}(m)}{dm} > 0, \frac{dr^{2*}(m)}{dm} > 0, \frac{ds^{2*}(m)}{dm} > 0,$ that is, given the total amount of market, the service pricing, profit, effort level of logistics providers have the negative correlation with the number of online stores and have the positive correlation with the service scale of logistics providers. The reason of this result is when the total amount of market is given, the number of online stores is more and the scale of each logistics providers is smaller, then the attractiveness to logistics service providers will be lower. On the contrary, the larger the scale of logistics providers is, the stronger the competitiveness will be. Therefore, there is Inference 3 as follows.

Inference 3: In the mode with service provided by 3PL providers, service price, profit and service level of 3PL providers have the negative correlation with service cost, have the negative correlation with the scale of online stores and have the positive correlation with the number.

In addition, because of $\frac{d\pi_i^{2*}}{d\theta} < 0,$ there is $\frac{dq_i^{2*}}{d\kappa} < 0, \frac{d\pi_i^{2*}}{d\kappa} < 0, \frac{dp^{2*}}{d\kappa} < 0,$ that is, online stores profit has the negative correlation with commission. Sales volume, profit and product price of online stores have the negative correlation with service cost. Considering the relativity of service scale and online stores number, according to $\frac{m}{2(n+1)} < \kappa,$ when

$\frac{m}{2(n+1)} < \kappa < \frac{1}{2},$ there is $\frac{dq_i^{2*}(n)}{dn} = \frac{dq_i^{2*}(m)}{dm} = \frac{\kappa(1-2\kappa)}{\left[2\kappa(n+1)-m\right]^2} > 0, \frac{d\pi_i^{2*}(n)}{dn} = \frac{d\pi_i^{2*}(m)}{dm}$ $= \frac{2(1-\theta)\kappa^2(1-2\kappa)}{\left[2\kappa(n+1)-m\right]^3} > 0$ When $\frac{m}{2(n+1)} < \kappa < 1 + \frac{n-m}{2},$ there is $\frac{dp_i^{2*}(n)}{dn} = \frac{dp^{2*}(m)}{dm}$ $= \frac{\kappa(2+n-m-2\kappa)}{\left[2\kappa(m+1)-m\right]^2} > 0.$ Sales volume, profit and product price of online stores have the positive correlation with service scale and online stores number. The result means that for online stores, when service cost is lower, service scale and online stores number will all show the positive scale effect. The less service scale is, the lower service cost must be. Therefore, there is Inference 4 as follows.

Inference 4: In the mode with service provided by 3PL providers, online stores profit has the negative correlation with commission. Sales volume, profit and product price of online stores have the negative correlation with unit service cost. When the service cost is lower, sales volume, profit and product price of online stores have the positive correlation with the number and scale of online stores.

According to $\frac{d\pi^{2*}}{d\theta} > 0,$ there is $\frac{dQ^{2*}}{d\kappa} < 0, \frac{d\pi^{2*}}{d\kappa} < 0,$ that is, platform profit has the positive correlation with commission and has the negative correlation with market scale, profit and service cost. Considering the relativity of the market scale, the number of online stores and service scale, there is $\frac{dQ^{2*}(n)}{dn} > 0, \frac{dQ^{2*}(m)}{dm} > 0.$ This result is in compliance with the characteristics of Cournot competition. The competition will be intensified and market scale will be expanded with number of online stores. At the same time, according to formula (6), the economy of scale of 3PL providers to provide service is significant, so average service cost is reduced and the demand is expanded by increasing the service scale. By $\frac{d\pi^{2*}(n)}{dn} = \frac{d\pi^{2*}(m)}{dm} = \frac{\theta\kappa^2(2\kappa-2\kappa n+2n-m)}{\left[2\kappa(n+1)-m\right]^3},$ considering the restraint conditions $\frac{m}{2(n+1)} < \kappa,$ because of $\frac{2n-m}{2(n+1)} - \frac{m}{2(n+1)} > 0,$ there is $\frac{d\pi^{3*}(n)}{dn} > 0, \frac{d\pi^{3*}(m)}{dm} > 0,$ when $\frac{m}{2(n+1)} < \kappa < \frac{2n-m}{2(n+1)}.$ This means that platform profit increases with online stores numbers and service scale when service cost is lower. If the service scale is given, this conclusion is established only when service cost is lower. Therefore, there is Inference 5 as follows.

Inference 5: In the mode with service provided by 3PL providers, platform profit has the negative correlation with commission, sales volume and profit have the negative correlation with service cost and sales volume has the positive correlation with online stores number and service scale. Platform profit has the positive correlation with service scale when service cost is lower. It is on the contrary when service cost is higher.

4.3 Mode III: PP

In PP mode, platform self-operates e-commerce business, $p_i = p$ and $q_i = Q$. Platform constructs and operates its own logistics service capability, so there is $s_i = s$. According to formulae (1) and (7), with a competitive equilibrium, we can get Lemma 3 as follows.

Lemma 3: In the mode of platform with self-operating e-commerce and logistics service, when $\kappa > \frac{1}{2}$, customer satisfaction is $s^{3*} = \frac{1}{2\kappa - 1}$, equilibrium price of product is $p^{3*} = \frac{\kappa}{2\kappa - 1}$, total sales volume of platform is $Q^{3*} = \frac{\kappa}{2\kappa - 1}$ and profit of platform is $\pi^{3*} = \frac{\kappa}{2(2\kappa - 1)} - F$.

See Appendix for the proof for Lemma 3.

It is easy to know by Lemma 3, $\frac{ds^{3*}}{d\kappa} < 0, \frac{dQ^{3*}}{d\kappa} < 0, \frac{d\pi^{3*}}{d\kappa} < 0.$ Obviously, in the mode of PP, logistics service cost is the main restrictive factor for operation. The reason is higher service cost will lead to lack of incentive for service level, will influence the customer satisfaction and then affect the operational performance. But analysing participant constraint of platform who self-operates logistics $\frac{\kappa}{2(2\kappa - 1)} \geq F$, there is $2 - \frac{2}{\kappa} \leq \frac{1}{2F}$. So, κ has the negative correlation with F. This means it will effectively expand the feasible space of the service cost when the logistics technology level is higher. Therefore, it is very necessary that the management level and technical level of logistics industry could be finely balanced when e-commerce platform considers selecting logistics mode. When the whole logistics industry becomes more and more matured and perfect, the development mode that is hard to be imagined may be not the problem anymore. Therefore, there is Inference 6 as follows.

Inference 6: In the mode of PP, logistics service cost is the main restrictive factor for the whole platform operation. Higher service cost will lead to a lack of incentive to service level. Advanced technical level of logistics industry can make up the disadvantage caused by higher service cost to a certain degree. Whether platform chooses self-operation logistics strategy or not, the key point is its own logistics service capability and the development level of logistics industry will be compared and finely get balanced.

4.4 Mode IV: TP

In TP mode, platform self-operates e-commerce and authorises logistics providers to provide the logistics service, so $p_i = p$ and $q_i = Q$. The service level and price of logistics providers are unique, $s_i = s$ and $w_i^T = w_T$. According to formulae (1), (8) and (9), with a competitive equilibrium, we can get Lemma 4 as follows.

Lemma 4: In the mode of TP, when $\kappa > \frac{1}{4}$, customer satisfaction is $s^{4*} = \frac{1}{4\kappa - 1}$, equilibrium price of service is $w_T^{4*} = \frac{2\kappa}{4\kappa - 1}$, equilibrium price of product is $p^{4*} = \frac{3\kappa}{4\kappa - 1}$, total sales volume of platform is $Q^{4*} = \frac{\kappa}{4\kappa - 1}$, profit of platform is $\pi^{4*} = \frac{\kappa^2}{(4\kappa - 1)^2}$ and profit of logistics providers is $r^{4*} = \frac{\kappa}{2(4\kappa - 1)}$.

See Appendix for the proof for Lemma 4.

By Lemma 4, it is easy to know $\frac{ds^{4*}}{d\kappa} < 0, \frac{dw_T^{4*}}{d\kappa} < 0, \frac{dr^{4*}}{d\kappa} < 0, \frac{dp^{4*}}{d\kappa} < 0, \frac{dQ^{4*}}{d\kappa} < 0,$ $\frac{d\pi^{4*}}{d\kappa} < 0.$ Obviously, in the mode of TP, logistics service cost is the main restrictive factor for platform operation. The reason is similar to Inference 8. However, because of 3PL transaction costs, compared with the mode III, increased service cost will influence the service level and there is a lack of incentive for service level. So, the higher the product price is, the less the sales and profit will be. Therefore, there is Inference 7 as follows.

Inference 7: In the mode of TP, logistics service cost is the main restrictive factor for platform operation. Compared with platform self-operation, logistics service level is with less incentive because of higher cost of 3PL transaction, so the product price will be higher and the sales and profit will be less.

5 Mode comparison

5.1 Level of logistics service

By Lemma 1 to 4, the level of logistics service is shown in Table 2.

Table 2 Service level in different logistics modes

Logistics modes	*I. PO*	*II. TO*	*III. PP*	*IV. TP*
Equilibrium constraint	$\frac{n}{2(n+1)} < \kappa$	$\frac{m}{2(n+1)} < \kappa$	$\frac{1}{2} < \kappa$	$\frac{1}{4} < \kappa$
Service level	$s^{1*} = \frac{n}{2\kappa(n+1) - n}$	$s^{2*} = \frac{n}{2\kappa(n+1) - m}$	$s^{3*} = \frac{1}{2\kappa - 1}$	$s^{4*} = \frac{1}{4\kappa - 1}$

It is easy to know by Table 2: $s^{1*} = \frac{1}{\kappa\frac{2(n+1)}{n} - 1}, s^{2*} = \frac{1}{\kappa\frac{2(n+1)}{m} - 1}, s^{3*} = \frac{1}{2\kappa - 1}$ and $s^{4*} = \frac{1}{4\kappa - 1}$, obviously, because $0 < \theta < 1$, it is easy to get conclusions as follows:

Conclusion 1 When $\frac{n+1}{2} \le m < n$, there is $s^{4*} \le s^{2*} \le s^{1*} < s^{3*}$.

Conclusion 2 When $m < \frac{n+1}{2}$, there is $s^{2*} \le s^{4*} \le s^{1*} < s^{3*}$.

Conclusion 3 When $n = 2$ and $m = 1$, there is $s^{4*} \le s^{2*} \le s^{1*} < s^{3*}$.

Through the analysis of above three conclusions, it is easy to find that the level of logistics services will be affected by three key factors: service cost, transaction cost and service scale. Transaction costs are the lowest in PP mode, but because of the monopoly, the service scale is smaller than the market scale of multi-oligopoly competition. Service scale in PO mode is the largest but there is transaction cost between platform and online stores. The results of equilibrium comparison show that the impact of transaction cost is greater than the service scale, so service in PP mode is better than that in PO mode. The transaction cost structure is same in the mode of TO and TP, but because of monopoly, service scale of the former is not the largest. Because of the service scale changes between the minimum and maximum to the latter, service level is depending on the comparison of service scale. When the service scale is large enough, the service level in TO mode will be higher than that in TP mode. Due to the impact of transaction cost and the service scale at the same time, service levels in the mode of TO and TP are always lower than that in the mode of PP and PO. Obviously, the service cost plays a decisive role on service level, but very small impact on the difference among modes; transaction cost has the greatest impact on the service difference and less impact on the service scale. Therefore, there is the proposition as follows.

Proposition 1: Service level of e-commerce logistics mode is determined by service cost, service scale and transaction cost. Service cost represents the professional ability of logistics service and has the greatest impact on the service level, then the transaction cost and the last the service scale. Under same service cost, service level in PP mode is the best and PO mode is the second. The difference of service level between TP mode and TO mode is determined by service scale. If the cost is too high when the platform would like to provide high level logistics service, TO mode will be the first option.

From this proposition, we can understand that because of better logistics service experience, JD who chooses PP mode got better reputation from customer, but it is just opposite on Taobao who chooses TO mode. Although fans of Taobao are criticising JD mode, 'Cainiao Network' invested and constructed by Mayun who is the founder of Alibaba Network Technology Co., Ltd. and his partners adopted TO mode which is most similar to PP mode. The 'Tmall Supermarket' has been operated under the mode, which is almost the mirror image of PP mode. It means that customer experience supported by logistics service is one of the core competencies in e-commerce competition.

5.2 Product price

By Lemma 1 to 4, the product price of different logistics service modes is shown in Table 3.

Table 3 Product price of different logistics service modes

Logistics modes	*I. PO*	*II. TO*	*III. PP*	*IV. TP*
Equilibrium constraint	$\frac{n}{2(n+1)} < \kappa$	$\frac{m}{2(n+1)} < \kappa$	$\frac{1}{2} < \kappa$	$\frac{1}{4} < \kappa$
Service level	$p^{1*} = \frac{\kappa(n+2)}{2\kappa(n+1)-n}$	$p^{2*} = \frac{\kappa(n+2)}{2\kappa(n+1)-m}$	$p^{3*} = \frac{\kappa}{2\kappa-1}$	$p^{4*} = \frac{3\kappa}{4\kappa-1}$

It is easy to know by Table 3: $p^{2*} \le p^{1*}$.

When $1 \le \kappa$, there are $p^{3*} \le p^{4*}$, $p^{1*} \le p^{4*}$ and $p^{3*} \le p^{2*}$. That is $p^{3*} \le p^{2*} \le p^{1*} \le p^{4*}$. The result shows that when the service cost is higher, product price is the highest in TP mode; it means monopoly operations, service cost-plus and transaction cost-plus are the main reasons for high price. Although, PP mode is monopoly pricing, the product price is lower than that in modes of PO and TO, however the latter two modes are price competitive but with transaction costs. This means that the impact of transaction cost on the product price is greater than that for monopoly operation. Product price in mode of PP are higher than that in logistics provider mode. It reflects the logistics service scale has a positive impact on product price.

When $\frac{1}{2} < \kappa < 1$, there is $p^{4*} < p^{3*}$, $p^{1*} < p^{3*}$ and $p^{4*} < p^{1*}$. Analyse $p^{4*} - p^{2*}$ and only consider the part of numerator $\varphi(p^{4*} - p^{2*})$, $\varphi(p^{4*} - p^{2*}) = 2\kappa(n-1) - 3m + n + 2$, if $m > \frac{2n-1}{3}$ and $p^{4*} - p^{2*}$, there is $p^{4*} \le p^{2*} \le p^{1*} \le p^{3*}$. If $\frac{2n-1}{3} < m$ and $p^{2*} < p^{4*}$, there is $p^{2*} \le p^{4*} \le p^{1*} \le p^{3*}$. Corresponding to the above conclusion is that when the service cost is low, product price of PP mode is the highest. However, product price of TP mode is lower than that in PP mode. This illustrates the impact of service cost on product price is greater than that by transaction cost. Only when the service scale is larger, the product price of TO mode is higher than that in TP mode. Because these two modes are with the same structure of service cost and transaction cost, which reflects the impact of the service scale is really less than that from above two kinds of costs, but it is also verifies the previous conclusions. Therefore, there is proposition as follows.

Proposition 2: Considering the situation in logistics service mode, the equilibrium price of e-commerce product is mainly impacted by service cost, transaction cost, monopoly operation and service scale with their relative importance in a descending order. When the service cost is higher, product price is the highest in the TP mode and is in decreasing order in the mode of PO, TO and PP, respectively. When the service cost is lower, product price is the highest in the mode of PP and is the second in the mode of PO. If service scale is larger, TO mode is rank at third, TP mode is the fourth. If the service scale is smaller, the result will be just in reverse.

This proposition shows that for homogeneous goods, different logistics service provide different service experience and also form different product price. Observing different sort of product price with the changes of impact factors on price, it is concluded that with the improvement of logistics technology and management level, the higher price is not caused by the cost-plus, but by experience utility increase in PP mode. High price caused by cost-plus is a competitive disadvantage and the high price resulted from utility increase is likely to be a competitive advantage.

The following is the data comparison of gross merchandise volume (GMV) between MaoTaoJu (http://maotaojvquan.com) of Alibaba and JD: in the second quarter of 2014, the MaoTaoJu was 501 billion yuan (RMB) with year-on-year growth of 45.1%; in the corresponding period of 2014, JD was 63 billion yuan with year-on-year growth of 107% and is 12.6% of MaoTaoJu. In the first quarter of 2015, the proportion of their GMV was 14.6%. In the second quarter of 2016, GMV of MaoTaoJu grew 24% year-on-year to reach 837 billion yuan and GMV of JD grew 47% year-on-year to reach 160.4 billion yuan, MaoTaoJu was 5.2 times as much as JD (Luo, 2016). Investigated homogeneous goods and compared with MaoTaoJu, the price in JD was higher, but it seems that it did not obstruct the fast marching steps in JD. This also means that the low price is not the killer of e-commerce; customer satisfaction is the key for competition. While continuing to reduce logistics service costs, the advantage of PP mode is more prominent and customer experience is more obviously improved.

5.3 Market scale and profit of online stores

By Lemma 1 to 4, there are online store performances in different logistics service modes as shown in Table 4.

Table 4 Online store performance in different logistics service modes

Logistics modes	*I. PO*	*II. TO*	*III. PP*	*IV. TP*
Constraint condition	$\frac{n}{2(n+1)} < \kappa$	$\frac{m}{2(n+1)} < \kappa$	$\frac{1}{2} < \kappa$	$\frac{1}{4} < \kappa$
Online store scale	$q_i^{1*} = \frac{\kappa}{2\kappa(n+1) - n}$	$q_i^{2*} = \frac{\kappa}{2\kappa(n+1) - m}$	——	——
Online store profit	$\pi_i^{1*} = \frac{\kappa^2}{[2\kappa(n+1) - n]^2}$	$\pi_i^{2*} = \frac{(1-\theta)\kappa^2}{[2\kappa(n+1) - m]^2}$	——	——

It is easy to know by Table 4: $q_i^{2*} \le q_i^{1*}$ and $\pi_i^{2*} \le \pi_i^{1*}$. It means both the market scale and profit in PO mode are better than those in TO mode for online stores. The reason is the PO mode is more advantageous in service scale to effectively save service cost at first. Secondly, PO mode will internalise part of external transaction to save transaction cost. Therefore, there is proposition as follows.

Proposition 3: PO mode will save more logistics service cost and transaction cost than that in TO mode via effectively using scale effect of logistics service and internalising part of external transaction. It will bring more product sale volume and more profit of online stores.

The preference and choice of online store are the basic prerequisite to choose TO mode of e-commerce platform. This is a major reason for the coexistence of many service modes [such as JD, Vip (http://www.vip.com), Amazon, Dangdang and Meituan]. Based on the reason found through above analysis, for opened platform, it is obviously that the online stores prefer to choose PO mode. Of course, online store preference is only the necessary condition for mode choice, the advantages and disadvantages for platform investment construction and operation of logistics service shall be balanced.

5.4 Market scale and profit of platform

By Lemma 1 to 4, there is platform performance in different logistics service modes as shown in Table 5.

Table 5 Platform performance of different logistics service mode

Logistics modes	*I. PO*	*II. TO*
Constraint condition	$\frac{n}{2(n+1)} < \kappa$	$\frac{m}{2(n+1)} < \kappa$
Platform scale	$Q^{1*} = \frac{n\kappa}{2\kappa(n+1) - n}$	$Q^{2*} = \frac{n\kappa}{2\kappa(n+1) - m}$
Platform profit	$\pi^{1*} = \frac{n\kappa}{1[2\kappa(n+1) - n]} - F$	$\pi^{2*} = \frac{n\theta\kappa^2}{[2\kappa(n+1) - m]^2}$
Logistics modes	*III. PP*	*IV. TP*
Constraint condition	$\frac{1}{2} < \kappa$	$\frac{1}{4} < \kappa$
Platform scale	$Q^{3*} = \frac{\kappa}{2\kappa - 1}$	$Q^{4*} = \frac{\kappa}{4\kappa - 1}$
Platform profit	$\pi^{3*} = \frac{\kappa}{2(2\kappa - 1)} - F$	$\pi^{4*} = \frac{\kappa^2}{(4\kappa - 1)^2}$

It is easy to know by Table 5: $Q^{4*} < Q^{2*} \le Q^{1*} < Q^{3*}$. It means that the market scale of platform is the largest in PP mode and the smallest in TP mode under any condition. At the same time, whether the platform will self-operate e-commerce business or provide e-commerce service only, market scale in PP mode is greater than that in TP mode.

By Table 5, there is $\pi^{1*} < \pi^{3*}$. It means that, platform self-operative e-commerce business will get more profit than that by only providing e-commerce services even with the same choice of self-operation logistics. But if 3PL is chosen, when only $\theta < \frac{[2\kappa(n+1) - m]^2}{n(4\kappa - 1)^2}$, there is $\pi^{2*} \le \pi^{4*}$ Platform self-operative e-commerce business will get more profit than that by just providing e-commerce services and the feasible region of θ will decrease sharply with the increasing of service scale of 3PL. However, the value of θ is so small that platform profit decreases sharply, so it will bring greater loss. It shows that for the platform self-operates e-commerce business, choosing self-operation logistics services are the strategy with more advantages. Those opened e-commerce platforms only provide trading services and the 3PL service is the more advantageous strategy.

By $\pi^{3*} - \pi^{4*} = \dfrac{\kappa(12\kappa^2 - 6\kappa + 1)}{2(2\kappa - 1)(4\kappa - 1)^2} - F,$ when $F \le f(\kappa) = \dfrac{\kappa(12\kappa^2 - 6\kappa + 1)}{2(2\kappa - 1)(4\kappa - 1)^2},$ there is $\pi^{4*} \le \pi^{3*}$. Obviously, for those platforms of self-operative e-commerce, only when the logistics technology is developed to a certain level and the investment to self-built logistics system is not too much, is it possible to implement the PP mode. By $\kappa > \dfrac{1}{2},$ there is $\dfrac{df(\kappa)}{d\kappa} = \dfrac{-2(4\kappa - 1)\left[\kappa(6\kappa + 1)(2\kappa - 1) + 1\right]}{2(2\kappa - 1)^2 (4\kappa - 1)^4} < 0.$ It means that the higher level of logistics management is, namely the lower logistics marginal cost κ is, the greater the feasible region F will be. It shows that with the development of logistics operation management level or logistics technology, PP mode will gradually become the priority choice of self-operation e-commerce platform.

By $\pi^{1*} - \pi^{2*} = \dfrac{n\kappa}{2\left[2\kappa(n+1) - n\right]} - F - \dfrac{n\theta\kappa^2}{\left[2\kappa(n+1) - m\right]^2},$ because $\dfrac{d\pi^{2*}}{dm} > 0,$ there is $\lim_{m \to n} \pi^{2*} = \hat{\pi}^{2*} = \dfrac{n\theta\kappa^2}{\left[2\kappa(n+1) - n\right]^2}.$ By $\pi^{1*} - \hat{\pi}^{2*} = \dfrac{n\kappa\left[2\kappa(n+1) - n - \theta\kappa\right]}{2\left[2\kappa(n+1) - n\right]^2} - F,$ when $F \le g(\kappa, \theta, n, m) = \dfrac{n\kappa\left[2\kappa(n+1) - n - \theta\kappa\right]}{2\left[2\kappa(n+1) - n\right]^2},$ there is $\pi^{2*} \le \pi^{1*}$. By calculation to know $\dfrac{dg(\kappa)}{d\kappa} = \dfrac{n\left\{-\left[2\kappa(n+1) - n\right](2\kappa + n) + n\theta\kappa(1 - 4\kappa)\right\}}{2\left[2\kappa(n+1) - n\right]^3},$ by $\dfrac{n}{2(n+1)} < \kappa,$ there is $2\kappa(n + 1) - n > 0$ and $\dfrac{1}{4} < \kappa,$ so we get $\dfrac{dg(\kappa)}{d\kappa} < 0.$ Namely, the feasible region of is decreased with the increasing of κ. Similarly, $\dfrac{dg(\theta)}{d\theta} < 0,$ that is the feasible region of F is decreased with the increasing of θ. The above results show when the logistics operation management level is lower or commission level is higher, the possibility for open e-commerce platform to adopt the PO mode will be smaller. In addition, $\dfrac{dg(n)}{dn} = \dfrac{n\kappa^2(2 + \theta)(2\kappa - 1)}{2\left[2\kappa(n+1) - n\right]^3},$ if given F, there is $\pi^{1*} - \hat{\pi}^{2*} = g(n) - F, \dfrac{d(\pi^{1*} - \hat{\pi}^{2*})}{dn} = \dfrac{dg(n)}{dn}.$ Obviously, when $\kappa > \dfrac{1}{2},$ there is $\dfrac{dg(n)}{dn} > 0.$ This result means that the advantage of PO mode is more obvious with increasing online stores scale or decreasing logistics service scale. In summary, if the opened platform of the logistics operation management level is higher and the commission level is relatively lower, it is more likely to adopt PO mode with increased online stores or decreased logistics service scale. So there is proposition as follows.

Proposition 4: Among all of the logistics service modes, market scale of PP mode is the largest and the PO mode is the second, then it is the TO mode and the smallest is the TP mode. For profitability, the PP mode is the relatively advantageous strategy to the integrative platform and the TO mode is more advantageous to the opened platform. With the development of logistics operation management level or logistics technology, the PP mode will become the priority choice of integrative platform. With better logistics operation management level and lower commission level and with the increased online stores or decreased logistics service scale, it will be more likely for the opened platform to adopt the PO mode.

In the real market, self-operation e-commerce platform always adopts the PP mode representing by Amazon and JD. The PP mode also happens to be most helpful to expand the market share and scale. Rapid growth GMV of JD mall also confirmed this conclusion. Open e-commerce platform prefers the TO mode at the beginning with Taobao as the representative. When the opened platform achieves a certain scale, it often chooses self-operation logistics service like Taobao began to operate 'Cainiao logistics' and Tmall also began to operate 'Tmall logistics'. Subsequently, developed platforms, such as Meituan, etc. arranged and constructed the system with self-operation logistics service from the beginning. These typical e-commerce platform practices have verified the above proposition.

5.5 Logistics service price and logistics provider profit

By Lemma 1 to 4, logistics service price and logistics provider profit in different logistics service modes are shown in Table 6.

Table 6 Logistics service price and logistics provider profit in different logistics service modes

Logistics modes	*I. PO*	*II. TO*	*III. PP*	*IV. TP*
Constraint condition	$\frac{n}{2(n+1)} < \kappa$	$\frac{m}{2(n+1)} < \kappa$	$\frac{1}{2} < \kappa$	$\frac{1}{4} < \kappa$
Service price	$w_S^{1*} = \frac{\kappa(n+1)}{2\kappa(n+1)-n}$	$w_T^{2*} = \frac{\kappa(n+1)}{2\kappa(n+1)-m}$	——	$w_T^{4*} = \frac{2\kappa}{4\kappa-1}$
Logistics provider profit	——	$r^{2*} = \frac{m\kappa}{2[2\kappa(n+1)-m]}$	——	$r^{4*} = \frac{\kappa}{2(4\kappa-1)}$

It is easy to know by Table 6: when $m < \frac{n+1}{2}$, there is $w_T^{2*} < w_T^{4*} < w_S^{1*}$. When $m \geq \frac{n+1}{2}$, there is $w_T^{4*} \leq w_T^{2*} < w_S^{1*}$ It means that logistics service price of e-commerce will be the highest in PO mode under any condition. From the perspective of price structure, logistics service outsourcing is advantageous for price comparing to self-operation. If the operation scale of online stores is very small, homogeneous competitors are in large number, then the market will tend to be perfect competition and product demand elasticity tends to 0. It will be difficult to play the scale effect of PO mode. At this time, online stores will tend to choose TO mode to increase profit by reducing the cost. This is just the reason why it is often announced in PO mode that no service will be provided to small stores. In addition, when the service scale of logistics providers is larger, the service price will be higher than that in TP mode. It means that market scale of logistics service will form the market forces cause higher service price. Similarly, when

$m \geq \frac{n+1}{2}$, there is $r^{2*} \geq r^{4*}$, larger service scale will bring more profit, which also proves the above conclusion. According to the Proposition 3 and Proposition 4, there is proposition as follows:

Proposition 5: Logistics service price in PO mode is often higher than that in TO mode. When logistics services scale is larger, the logistics providers prefer to provide services to the opened platform rather than integrated platform. When online store is under a highly competitive market environment, the TO mode is the better choice. When the opened platform belongs to oligopoly competition, online stores will prefer the PO mode, but only when the logistics operation management level is higher and commission level is lower, with the expansion of online stores scale, will the platform operators have more incentive to provide the service.

6 Conclusions and future works

Based on the background of e-commerce platform market with multi-oligopoly competition, the improved Cournot game model with considering the customer satisfaction and service level is presented in this paper and is used to compare and analyse the mechanism interpretation of logistics service modes that have attracted much attention in platform economy and their market applicability.

6.1 Conclusions

Although the models of this paper are based on B2C market, the basic connotation of this model has a more generous representation for platform economy. The most direct market is B2B, C2C, especially the more diversified O2O market where there is also the problem to select the logistics service mode. Others include professional wholesale (retail) market under different market environment, different industries and with different scale comprehensive supermarket, department stores and shopping plaza, regional and international trade hub, even diversified, multi plant operation of manufacturing enterprises, etc. There is similar internal business logic in those scenes with Taobao and JD. Because the management decision shall be always in subject to management objectives, they would choose the appropriate logistics service mode, when the platform or online stores need to implement different management objectives. The analysis of this paper may give the following implications on participants of platform economy.

Implication 1: PO mode is the most effective strategy to improve the service level. Reducing marginal service cost will make maximum improvement on service with minimum impact on service scale.

The best service level of e-commerce logistics is mainly determined by the marginal service cost, transaction cost and service scale. And the greatest impact is service cost. At the same time of serviceability, the main factor that affects the service level is transaction cost. The service scale that is often concerned has the smallest impact. If the impact conditions are the same, then no matter it is open e-commerce platform or self-operation platform, the PO mode of logistics service brings better customer satisfaction than the TO mode. If the logistics serviceability of platform is not enough and the improvement cost is higher, the 3PL service will be chosen, because there will be always 3PL providers who can provide higher cost-effective service in the market.

Implication 2: TO mode is an advantageous strategy of opened platform price competition and there is no price competitive advantage strategy for integrated platform.

The equilibrium price of e-commerce is mainly influenced by service cost, transaction cost, monopoly operation and service scale which relative importance is in descending order. From Proposition 2, no matter how service cost changes, product price in PO mode is higher than that in TO mode. For the integrated platform, when the service cost is higher, the product price in PP mode is lower, but it is less profitable according to Proposition 4. When the service cost is lower, the product price is lower in TP mode, but the profit is also very low. So it is difficult for the integrated platform to find the strategy with price competition advantage and the product price should always be higher.

Implication 3: PO mode is always the first option for online stores, whether to pursue of sales scale or profitability.

It is still the mail service mode of many opened platforms to use TO mode, but PO mode is always the best choice for online stores because it can bring more sales volume and more profit for online stores. There is no resistance from online stores if PO mode is chosen, but the choice of TO mode for a platform will ultimately depend on market forces and online stores in the platform are always at weaker position. Online stores have certain market forces only in the early development stage of platform and show in Proposition 4 that the platform scale is too small to provide logistics services, but only to attract online stores by reducing the commission or providing subsidies.

Implication 4: PP mode is an advantageous strategy for all e-commerce platforms to pursue market share.

With the rapid expanding of the market scale, working hard to occupy the absolute advantage market share and trying to suppress market space of competitors are the most important means for e-commerce competition. In early development stage of e-commerce, supporting role of market expansion strategy has not been paid with enough attention for logistics service mode. Amazon, Meituan and especially the rapid growth GMV of JD provided very good evidence of this strategy for PP mode. At present, almost all of large e-commerce platforms have begun to develop PP mode, which also illustrates this statement.

Implication 5: With the gradual improvement of logistics industry development level, PO mode will gradually become an advantageous strategy of e-commerce platform to get more profit.

The development of logistics industry is an important reason to decide if the logistics service mode is good or not. Improvement of logistics operation efficiency and advancement of logistics technology and equipment capacity will effectively reduce the entry threshold of logistics service market and logistics activities will become one of the main value-added activities in value chain. PP mode will become the first option of integrated platform. After the opened platform achieves a certain operation scale, it will be more likely to adopt PO mode.

Implication 6: Service price in TO mode is lower and logistics providers prefer to provide service to the opened platform.

When logistics service scale is larger, logistics providers have more market forces to face a large number of middle and small online stores. Especially, when the platform scale and online stores volume are very large and the situation of online stores are more and more approximating to perfect competition market, lower logistics service price will be more attractive to online stores and TO mode is the better choice. Instead, when the 3PL provider provided services to the integrated platform, it will always face a strong negotiator. So generally speaking, it will be at a disadvantageous position.

6.2 Major contributions

This study shows the basic rules of e-commerce platform competitive behaviour to a certain degree, which can provide more specific decision-making support for the selection of e-commerce logistics service mode. According to the main conclusions of this paper, when the decision objective is different, the selection of logistics service mode can refer to Table 7.

Table 7 Logistics mode selection driven by different decision objectives

		Mode selection			
		PO	*TO*	*PP*	*TP*
Decision objective	Service level	√√√	√√	√√√√	√
	Profit ability	√√	√	√√	√
	Price advantage	√	√√√	√	√√
	Market share	√√√	√√	√√√√	√

6.3 Future research

On the basis of current research, the introduction of network effects, asymmetric information and uncertain environment assumption, the impact of information interaction, agent cooperation and other variables will be considered, the mechanism of competition will be analysed at the micro level in the future.

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Appendix

Proof of Lemma 1

According to formulae (1), (2) and (3), profit of online stores is

$$\pi_i = \left(1 - \sum_{i=1}^{n} q_i + s_i\right) q_i - w_S q_i. \tag{10}$$

The optimal yield is determined by online store. This paper references the methods of Bergstrom and Varian (1985) to solve the optimal equilibrium of profit formula. By $\frac{d^2\pi_i}{dq_i^2} = -2 < 0$ and for all $i \in [1, n]$, there is optimal equilibrium condition $\frac{d\pi_i}{dq_i} = 0$ which satisfies $\max \pi_i(q_i, q_{-i}^*)$, then we can achieve n first-order conditions $1 - 2q_i - \sum_{j=1,\, j\neq i}^{n} q_i + s_i - w_S = 0$. According to $Q = \sum_{i=1}^{n} q_i$, $s_i = s$, $w_i^S = w_S$ and to sum all $q_i (i \in [1, n])$, we can get $n - Q - n_Q + n_s - nw_M = 0$, therefore, platform sales volume of Cournot equilibrium is $Q = \frac{n(1 + s - w_S)}{n+1}$. According to the hypothesis, all of online stores have symmetrical structure in this paper: $Q = nq_i$, so

$$q_i = \frac{1 + s - w_S}{n+1},\ p_i = p = \frac{1 + s + nw_S}{n+1} \tag{11}$$

then, take formula (11) into formula (10), there is profit of platform:

$$\pi = \frac{n(1 + s - w_S) w_S}{n+1} - \frac{1}{2}\kappa s^2 - F \tag{12}$$

Logistics service price w_S is determined by platform. By $\frac{d^2\pi}{dw_S^2} = -\frac{2n}{n+1} < 0$, there is optimal equilibrium condition $\frac{d\pi}{dw_S} = 0$ which satisfies $\max\pi(w_S)$, we can achieve

$$w_S = \frac{1+s}{2} \tag{13}$$

then, take formula (13) into formula (12), there is profit of the platform

$$\pi(s) = \frac{n(1+s)^2}{4(n+1)} - \frac{1}{2}\kappa s^2 - F \tag{14}$$

Service level s is determined by platform. When $\frac{n}{2(n+1)} < \kappa$, $\frac{d^2\pi}{ds^2} < 0$, there is optimal equilibrium condition $\frac{d\pi(s)}{ds} = 0$ which satisfies $\max\pi(s)$, we can achieve $\frac{n(1+s)}{2(n+1)} - \kappa s = 0$. Therefore,

$$s^{1*} = \frac{n}{2\kappa(n+1)-n} \tag{15}$$

then, take formula (15) into formulae (13), (11), (10), (14) and $Q = nq_i$, we can get Lemma 1.

Proof of Lemma 2

According to formulae (1), (4), (5) and (6), profit of online stores is

$$\pi_i = (1-\theta)\left(1-\sum\nolimits_{i=1}^{n} q_i + s_i - w_i^T\right)q_i \tag{16}$$

By $\frac{d^2\pi_i}{dq_i^2} = -2 < 0$, then for all $i \in [1, n]$, there is optimal equilibrium condition $\frac{d\pi_i}{dq_i} = 0$ which satisfies $\max \pi_i(q_i, q_{-i}^*)$, we can achieve n first-order conditions: $1-2q_i -\sum\nolimits_{j=1,\, j\neq i}^{n} q_i + s_i - w_i^T = 0$. To sum all $q_i(i \in [1, n])$, we can get $n-Q-nQ +\sum\nolimits_{i=1}^{n} s_i - \sum\nolimits_{i=1}^{n} w_i^T = 0$. Therefore, platform sales volume of Cournot equilibrium is $Q = \frac{n+\sum\nolimits_{i=1}^{n} s_i - \sum\nolimits_{i=1}^{n} w_i^T}{n+1}$. According to the hypothesis, the market structure is symmetrical: $w_i^T = w_T$, $s_i = s$ and $Q = nq_i$, so

$$Q = \frac{n(1+s-w_T)}{n+1},\ q_i = \frac{1+s-w_T}{n+1},\ p_i = p = \frac{1+s+nw_T}{n+1} \tag{17}$$

then, take formula (17) into formulae (5) and (6), we can get the profit of platform

$$\pi = \sum\nolimits_{i=1}^{n} \theta\left(p_i - w_i^T\right)q_i = \frac{\theta n(1+s-w_T)^2}{(n+1)^2} \tag{18}$$

and the profit of logistics providers

$$r = mw_T q_i - \frac{1}{2}\kappa s^2 = \frac{mw_T(1+s-w_T)}{n+1} - \frac{1}{2}\kappa s^2 \tag{19}$$

Service price w_T is determined by logistics provider by $\frac{d^2\pi}{dw_T^2} = -\frac{2m}{n+1} < 0$, there is optimal equilibrium condition $\frac{d\pi}{dw_T} = 0$ which satisfies $\max\pi(w_T)$, we can achieve

$$w_T = \frac{1+s}{2} \tag{20}$$

then, take formula (20) into formula (19), we get

$$r(s) = \frac{m(1+s)^2}{4(n+1)} - \frac{1}{2}\kappa s^2 \tag{21}$$

Service level s is determined by logistics provider. When $\frac{m}{2(n+1)} < \kappa, \frac{d^2 r(s)}{ds^2} < 0,$ there is optimal equilibrium condition $\frac{d\pi(s)}{ds} = 0$ which satisfies max$\pi(s)$, we can achieve $\frac{m(1+s)}{2(n+1)} - \kappa s = 0$. That is

$$s^{2*} = \frac{m}{2\kappa(n+1) - m} \tag{22}$$

firstly, take formula (22) into formula (20), then take formulae (22) and (20) into formula (17), at last, take formulae (22), (20) and (17) into formulae (16), (18) and (19), we can get Lemma 2.

Proof of Lemma 3

According to formulae (1) and (7), profits of platforms is

$$\pi = (1 - Q + s)Q - c_i^s - F \tag{23}$$

Obviously, $\frac{d^2\pi}{dQ^2} = -2 < 0,$ there is optimal equilibrium condition $\frac{d\pi}{dQ} = 0$ which satisfies max$\pi(Q)$, we can obtain a first-order conditions $1 - 2Q + s = 0$, therefore, the platform sales volume of Cournot equilibrium is

$$Q = \frac{1+s}{2} \tag{24}$$

then, take formula (24) into formula (23), we can get the profits of platform

$$\pi = \frac{(1+s)^2}{4} - \frac{1}{2}\kappa s^2 - F \tag{25}$$

Service level s is determined by platform, when $\kappa > \frac{1}{2},$ there is optimal equilibrium condition $\frac{d\pi(s)}{ds} = 0$ which satisfies max$\pi(s)$, we can achieve $\frac{1+s}{2} - \kappa s = 0.$ That is

$$s^{3*} = \frac{1}{2\kappa - 1} \tag{26}$$

then, take formula (26) into formulae (24), (1), (23) and (25), we can get Lemma 3.

Proof of Lemma 4

According to formulae (1), (8) and (9), profit of platform (namely online stores) is

$$\pi = (1 - Q + s - w_T)Q \tag{27}$$

Obviously, $\frac{d^2\pi}{dQ^2} = -2 < 0,$ there is optimal equilibrium condition $\frac{d\pi}{dQ} = 0$ which satisfies max$\pi(Q)$, we can achieve a first-order conditions: $1 - 2Q + s - w_T = 0$. Therefore, the platform sales volume of Cournot equilibrium is

$$Q = \frac{1 + s - w_T}{2} \tag{28}$$

then, take formula (28) into formula (9), we can get the profits of logistics providers

$$r = \frac{w_T(1 + s - w_T)}{2} - \frac{1}{2}\kappa s^2 \tag{29}$$

Service price w_T is determined by logistics providers. By $\frac{d^2\pi}{dw_T^2} = -1 < 0,$ there is optimal equilibrium condition $\frac{d\pi}{dw_T} = 0$ which satisfies max$\pi(w_T)$, we can achieve

$$w_T = \frac{1 + s}{2} \tag{30}$$

then, take formula (30) into formula (29), the function of logistics provider profit is

$$r = \frac{(1 + s)^2}{8} - \frac{1}{2}\kappa s^2 \tag{31}$$

Service level s is determined by logistics providers. When $\kappa > \frac{1}{4}$ and $\frac{d^2 r}{ds^2} = \frac{1}{4} - \kappa < 0,$ there is optimal equilibrium condition $\frac{d\pi(s)}{ds} = 0$ which satisfies max$\pi(s)$, we can achieve $\frac{1 + s}{4} - \kappa s = 0.$ Therefore,

$$s^{4*} = \frac{1}{4\kappa - 1} \tag{32}$$

then, take formula (32) into formulae (30), (28), (1), (27) and (31), we can get Lemma 4.