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Xiao Yu
National Engineering Laboratory for E-Commerce Technology, Department of Automation, Tsinghua University, Beijing 100084, China

Yueting Chai
National Engineering Laboratory for E-Commerce Technology, Department of Automation, Tsinghua University, Beijing 100084, China

Yi Liu
National Engineering Laboratory for E-Commerce Technology, Department of Automation, Tsinghua University, Beijing 100084, China

Hongbo Sun
National Engineering Laboratory for E-Commerce Technology, Department of Automation, Tsinghua University, Beijing 100084, China

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Infra-Marginal Analysis Model for Provision Mode Selection for E-commerce Services

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Abstract: E-commerce has grown extraordinarily since the emergence of the internet, and many types of services are employed to accelerate this process. Service quality and productivity are two critical indicators to evaluate the competitiveness of e-commerce companies. Deciding which provision mode of e-commerce services (buy, sell, or self-provide) to adopt is a key operational strategy issue. This paper investigates the conditions and limitations of e-commerce services' optimal supply modes, and proposes a cost oriented infra-marginal model where service demand is considered an exogenous variable due to its non-elastic and unprofitable characteristics. By analyzing the main impact factors of this model, this paper infers provision mode selection strategies, which are determined by four factors: transaction cost, service price, service demand, and competitive advantages. Decision trees are derived from these strategies to help e-commerce companies make appropriate decisions. Finally, the proposed model's feasibility is verified by two case studies.

Key words: e-commerce services; provision mode selection; e-commerce; infra-marginal analysis; cost minimizing

1 Introduction

E-commerce services are the foundation of e-commerce trade. Expanding the scale of e-commerce markets generates additional e-commerce service categories. Zwass defined e-commerce services by presenting an e-commerce framework consisting of three meta-levels: infrastructure, services, and products and structures. The meta-level of services consists of providing secure messaging and enabling services for e-commerce[1], such as online auctions, electronic payments, Certificate Authentication (CA), logistics, copyright protection, electronic contracts, and reputation systems. Services are always deemed to be the same as products in neoclassical economics[2], where service price is determined by equilibrium of demand and supply. However, most e-commerce services have special features: non-elastic demand and non-direct profitability.

Because e-commerce services are consumed when e-commerce trading happens, service demand is determined by the amount of trade orders. There is no trade-off between quantity and service price, which results in non-elastic demand. Free or extremely low price services always emerge in e-markets as e-market operators have the option to profit from advertisements and sponsored searches rather than paid services[3]. An e-commerce vendor's only motivation for providing e-commerce services is to improve service quality and attract more customers. Since e-commerce services do not bring direct revenue, a profit-oriented model is not applicable, so a cost-oriented model is employed instead. The two features of non-elastic demand and non-direct profitability are not attributes of e-commerce services alone, but also of some traditional services such as after sales' service and call centers.

Provision mode refers to the e-commerce company's strategy concerning how many services they should

• Xiao Yu, Yueting Chai, Yi Liu, and Hongbo Sun are with the National Engineering Laboratory for E-Commerce Technology, Department of Automation, Tsinghua University, Beijing 100084, China. E-mail: yuxiao84@mail.tsinghua.edu.cn; chaiyt@mail.tsinghua.edu.cn; yiliu@mail.tsinghua.edu.cn; sunhongbo02@tsinghua.org.cn.
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buy, sell, and self-provide. Definition of these provision modes is derived from the specialization modes in Yang's theory regarding the division of labor[4]. Yang presented a theory of division of labor by employing infra-marginal analysis based on increasing returns to specialization in a microeconomics approach. The division modes of labor, consisting of autarky and different types of trading, are similar to those in service provision modes. The shift between division modes depends on individuals' optimal decisions, which are determined by trade-offs between transaction costs and specialization effectiveness.

A provision mode selection can be classified into an optimization problem with achieving minimum cost as the objective and the amount of bought, sold and self-provided services as the control variables. In keeping with the theory of infra-marginal analysis[5], this paper derives five feasible provision modes: buy only, sell only, autarky, buy and self-provide, and sell and self-provide. The choice of optimal provision mode is determined by four exogenous variables: transaction cost, service price, service demand, and competitive advantages.

Cost function reflects the relationship between the number of provided services and the opportunity cost of invested resources in service production. The cost function characteristics greatly impact optimal solutions. As a trade-off exists between automation and labor in service industries[6], cost function characteristics vary with different service types. Because labor factors contribute to both increasing marginal costs and zero fixed costs[7], and Information Technology (IT) factors (reflecting automation level) contribute to both constant marginal costs and positive fixed costs[8], the division of investment in labor and IT determines if marginal costs will increase or remain constant. For example, logistics relying on more labor have increasing marginal costs; online auctions almost entirely relying on IT have constant marginal costs.

Considering the above factors, in order to address the optimization problem of provision modes, this paper presents a cost-minimizing model by considering special features of e-commerce services. Assuming two types of marginal costs, namely increasing or constant, the optimal bought, sold, and self-provided service amounts in each mode are formalized by employing infra-marginal analysis. Then, the optimizing decision is achieved by comparing the optimum cost of each provision mode. The optimizing decision shifts along with changes in exogenous variables, such as service demand, service price, transaction costs, and technical advantages.

2 Related Work

Since this paper has close relationship with research in the fields of service productivity, e-commerce services, and provision mode selection, this section offers a brief introduction.

2.1 Service productivity

Current research trends on service productivity emphasize relationships between customer satisfaction, service productivity, service quality, and profitability. Many findings support the conclusion of service quality exerting a positive impact on customer satisfaction and profitability, revealing a trade-off between service productivity and service quality[9]. Rust et al.[10] proposed an empirical analysis to address the issue of which quality/profitability emphasis (revenue expansion, cost reduction, or both) is most effective. They conclude that revenue expansion emphasis produces better results than either other option. In addition, Rust and Huang[6] presented a trade-off between automation and labor, and proposed that service productivity should be managed as a strategic decision variable to be optimized. Calabrese[11] proposed a managerial model to identify key causes explaining the foundations of trade-offs between service productivity and perceived service quality. Gronroos and Ojasalo[12] found that the underlying assumptions of manufacturing-based productivity do not hold for service productivity, e.g., constant quality assumptions. Based on this analysis, they offer a service productivity model wherein service productivity is a function of internal, external, and capacity efficiencies.

These researches all emphasize the importance of service quality. In applying these findings to e-commerce services, however, special attention should be paid to this forum's distinctive characteristics. For example, the assumption that labor endowment positively impacts service quality does not always hold for e-commerce services, which are impacted by both labor and IT factors. In fact, labor may have no relationship with service quality when e-commerce does not require it.

2.2 E-commerce services

With the rapid development of e-commerce, an increasing volume of researches have focused on e-commerce services. Rust and Kanman[13] proposed that the emergence of e-services challenges many traditional assumptions regarding using the online environment to raise profits. This theory is based less on reducing costs through automation and increased efficiency than on expanding revenues through enhancing services and building profitable customer relationships. Goldmanis et al.[14] investigated equilibrium market structure changes spurred by the introduction of e-commerce tools that reduced consumers' search costs. In addition, they predicted that smaller establishments declined in number whereas larger establishments grew increasingly dominant. Rabinovich et al.[15] examined both conceptually and empirically the question of why e-commerce firms incorporated new services providers in their distribution channels, such as logistics services. They employed transaction cost theory to determine that low levels of asset specificity and uncertainty drove e-commerce firms to establish these relationships.

The above researches all point out the novel nature of e-commerce services, which poses many new challenges. In such circumstances, e-commerce firms cannot be deemed as only playing one role in the service trade, such as buyer or seller. As a matter of fact, they often play multiple market roles simultaneously, which induces a strategy problem of which provision mode (buy, sell, and self-providing) for a specific service is most cost-efficient. Provision mode selection strategy is important not only to decision making but also to e-commerce firms' general equilibrium analysis, for it impacts two market forces: demand and supply, which in turn determine the market structure of e-commerce services.

2.3 Provision mode selection

Yang[4] presented a theory on the division of labor by employing infra-marginal analysis based on the concept of increasing returns to specialization used in the microeconomics approach. The division modes of labor, consisting of autarky and different types of trading, are similar to service provision modes. Shifts between division modes depend on individuals' optimal decisions, which are determined by trade-offs between transaction costs and specialization effectiveness[4]. Yang's theory offers a good approach to analyze trading participants' decisions, but the theory cannot fully explain some phenomena in the e-commerce market by simply substituting consumer-producer individuals with e-commerce companies. For example, some e-commerce companies self-produce and buy the same services simultaneously, an impossible behavior pattern in traditional division of labor theories. One example, 360buy.com in China, uses a self-built logistics service and employs third party logistics services at the same time. In addition, two other assumptions are unsuitable for e-commerce services: increasing returns to specialization and ex-ante identical consumer-producers. Increasing returns to specialization motivates division levels of labor, but decreasing costs to e-commerce service provided are impossible for e-commerce companies. Ex-ante identical assumption means that all consumer-producers have identical budget constraints, which is both impractical and unlikely when applied to companies.

3 Infra-Marginal Analysis Model

3.1 Assumptions

Assumption 1 Each e-commerce company's service demand is exogenous and fixed in the short term.

Assumption 1 reflects the special features of e-commerce services: non-elastics demand and unprofitability. The exogenous demand assumption has been used in analysis of a dynamic game approach to price competition in telecommunication industry[16].

Assumption 2 Wage rates are fixed in the short run.

A fixed wage rate is widely used in researches on services[17]. Because the wage rate is always determined by equilibrium of labor demand and supply, in reference to a specific service, assuming a fixed wage rate for a particular type of labor helps focus on market's service trade without considering the labor market's influence.

Assumption 3 Service quality of a specific service, even when provided by different firms, is unique.

Service quality is an important factor in researches on service, as it always impacts customer satisfaction[9]. However, different levels of quality can be interpreted as different types of services. The analysis model used in this study mainly focuses on decision optimization for provision modes of the same service type.

Assumption 4 Marginal costs of labor per service increase. Costs of IT include both fixed costs and constant marginal costs.

Microeconomics makes a general assumption of increasing marginal costs for labor per service[7] due to other factors' limitations and added management costs for labor increases. Information systems are the central IT factor in e-commerce services. Investments in design, development, and implementation of information systems belong to fixed costs, and spending on operating information systems belongs to constant marginal costs[8].

Therefore, in e-commerce services, cost functions depend heavily on the division of investment between labor and IT. This division, in turn, is determined by e-commerce service types.

Assumption 5 Marginal cost per service is either increasing or constant.

Following on from Assumption 4, marginal cost per service is impacted by two forces: labor and IT. If provision of an e-commerce service needs no labor, marginal cost remains constant. Otherwise, marginal costs always increase.

3.2 Cost-minimizing model of e-commerce services

This paper denotes D_i as the i-th e-commerce provider's service demand. This provider self-provides x_i units of service, buys x_i^{d} units from other providers, and sells x_i^{s} units at service price p. Trading services among providers are assumed to incur an iceberg-type transaction cost[18], which means the provider only receives kx_i^{d} units of service when buying x_i^{d} units of service, with $0 < k < 1$. The transaction cost is $(1-k)x_i^{\mathrm{d}}$. This paper denotes l_i as costs of the i-th e-commerce provider for self-provided services. The single-service cost model is as follows:

$$\min C_i = l_i + px_i^{\mathrm{d}} - px_i^{\mathrm{s}} \tag{1}$$

$$l_i = f_i(x_i + x_i^{\mathrm{s}}) \tag{2}$$

$$x_i + kx_i^{\mathrm{d}} = D_i, x_i \geqslant 0, x_i^{\mathrm{d}} \geqslant 0, x_i^{\mathrm{s}} \geqslant 0 \tag{3}$$

Equation (1) represents the optimization objective of an e-commerce service provider seeking to minimize the total cost of this single service. The total cost consists of investment l_i for producing services, payment for services purchased, and revenue (minus cost) from selling services to others.

Equation (2) represents the e-commerce service's production function. The traditional neoclassical economics production function requires factor investments as inputs and product amounts as output. In contrast, this e-commerce service production function takes investment in the form of capital as output, and amount of services as input.

Equation (3) contains the necessary constraints. Equation $x_i + kx_i^{\mathrm{d}} = D_i$ means that sum of self-provided services and purchased services should satisfy the entire service demand.

Lemma 1 An e-commerce service provider does not buy and sell the same service.

Proof Cost equation can be derived from Eqs. (1)-(3) as follows:

$$C_i = f_i(D_i - kx_i^{\mathrm{d}} + x_i^{\mathrm{s}}) + p(x_i^{\mathrm{d}} - x_i^{\mathrm{s}}) \tag{4}$$

If $x_i^{\mathrm{d}} > x_i^{\mathrm{s}}$, let $x_i^{\mathrm{d}} - x_i^{\mathrm{s}} = \Delta x$, then $C_i = f_i(D_i - k\Delta x + (1-k)x_i^{\mathrm{s}}) + p\Delta x$, because $\partial f_i / \partial x_i^{\mathrm{s}} > 0$ and $x_i^{\mathrm{s}} \geqslant 0$. When $x_i^{\mathrm{s}} = 0$, C_i reaches minimum. If $x_i^{\mathrm{d}} < x_i^{\mathrm{s}}$, then the reverse also holds. ■

From Lemma 1, the cost model yields five modes, shown in Table 1.

(1) When $x_i > 0$, $x_i^{\mathrm{d}} > 0$, and $x_i^{\mathrm{s}} = 0$, the mode named PB (Provide and Buy) means that the service provider both self-provides and buys services. Cost of PB mode becomes $C_i = f_i(D_i - kx_i^{\mathrm{d}}) + px_i^{\mathrm{d}}$.

(2) When $x_i > 0$, $x_i^{\mathrm{d}} = 0$, and $x_i^{\mathrm{s}} > 0$, the mode named PS (Provide and Sell) means that the service provider both self-provides and sells services. Cost of PS mode becomes $C_i = f_i(D_i + x_i^{\mathrm{s}}) - px_i^{\mathrm{s}}$.

(3) When $x_i > 0, x_i^{\mathrm{d}} = 0$, and $x_i^{\mathrm{s}} = 0$, the mode named Autarky means that the provider only self-provides services (neither buys nor sells services). Cost of Autarky mode becomes $C_i = f_i(D_i)$.

(4) When $x_i = 0$, $x_i^{\mathrm{d}} > 0$, and $x_i^{\mathrm{s}} = 0$, the mode named BO (Buy Only) means that the provider only buys services. Cost of SO mode becomes $C_i = px_i^{\mathrm{d}}$.

(5) When $x_i = 0$, $x_i^{\mathrm{d}} = 0$, and $x_i^{\mathrm{s}} > 0$, the mode named SO (Sell Only) means that the provider only sells services. Cost of SO mode becomes $C_i = f_i(x_i^{\mathrm{s}}) - px_i^{\mathrm{s}}$.

The situation with $x_i = 0$, $x_i^{\mathrm{d}} = 0$, and $x_i^{\mathrm{s}} = 0$ is meaningless. PB, PS, Autarky, and BO modes have precondition $D_i > 0$. SO mode has precondition $D_i = 0$. Therefore, pure service providers with no demand have to choose SO mode or quit the market. However,

Table 1 Five modes of the single service cost model.

Mode	x_i	x_i^{d}	x_i^{s}	C_i
PB (Provide & Buy)	+	+	0	$f_i(D_i - kx_i^{\mathrm{d}}) + px_i^{\mathrm{d}}$
PS (Provide & Sell)	+	0	+	$f_i(D_i + x_i^{\mathrm{s}}) - px_i^{\mathrm{s}}$
Autarky	+	0	0	$f_i(D_i)$
BO (Buy Only)	0	+	0	px_i^{d}
SO (Sell Only)	0	0	+	$f_i(x_i^{\mathrm{s}}) - px_i^{\mathrm{s}}$

Notes: Symbol "+" represents positive value, "0" is zero.

providers with positive demand have four choices, and their optimal decision forms the main focus of the following analysis.

In order to simplify the following analysis, this paper presents a specific cost function of service as follows:

$$f_i(x) = a_i x^{\alpha} + b_i \tag{5}$$

In Eq. (5), $a_i > 0$ represents the exogenous endowment advantage, $b_i > 0$ represents the fixed cost, and α represents the investment division of two factors. The value α increases along with the average labor requirement. The service needs nearly no labor when $\alpha = 1$, representing the situation where marginal cost is entirely spent on IT operations, such as e-payments and search engine services.

4 Decisions for Constant Marginal Costs

If an e-commerce service has constant marginal costs, the service production function is linear in form of $f_i(x) = a_i x + b_i$.

Proposition 1 If an e-commerce service has constant marginal costs ($\alpha = 1$), no provider will choose PB mode.

Proof If $f_i(x) = a_i x + b_i$, then PB mode's cost function is

$$C_i = a_i(D_i - kx_i^{\rm d}) + b_i + px_i^{\rm d} = (p - a_i k)x_i^{\rm d} + a_i D_i + b_i \tag{6}$$

where $0 \leqslant x_i^{\rm d} \leqslant D_i/k$. The C_i in Eq. (6) reaches minimum at corner solution $x_i^{\rm d} = 0$ or $x_i^{\rm d} = D_i/k$. The first equals Autarky mode, while the latter equals BO mode. ■

Therefore, providers with service demand $D_i > 0$ have three choices: PS, Autarky, and BO modes. Providers with no service demand, $D_i = 0$, can only choose SO mode.

The marginal cost a_i reflects the levels of IT operation technology and methods adopted by providers, which tend to be the same in the long term. Therefore, this analysis begins with an assumption of identical marginal costs, that is $a_i = a$.

4.1 Identical constant marginal costs

Proposition 2 When provider's marginal costs are constant ($\alpha = 1$) and identical ($a_i = a$), if $p < a$, all providers can only choose Autarky mode.

Proof If $p < a$, check the difference between the costs of PS mode and of Autarky mode:

$$\Delta C = C_i^{\rm PS} - C_i^{\rm A} = a_i(D_i + x_i^{\rm s}) - px_i^{\rm s} - aD_i = (a-p)x_i^{\rm s} \tag{7}$$

is always positive. Therefore, Autarky mode is more cost-efficient than PS mode. Considering providers with no demand who have to choose SO mode, its cost $(a - p)x_i^{\rm s} + b_i$ increases with $x_i^{\rm s}$, meaning that the optimal solution is to sell no services. Specifically, if $p < a$, no providers are willing to sell services, then meaning no one can buy services, so therefore, all providers have to choose Autarky mode. ■

Proposition 3 When providers' marginal costs are constant ($\alpha = 1$) and identical ($a_i = a$): (1) If $p < k(a + b_i/D_i)$, provider i's cost of BO mode is less than Autarky mode. (2) If $a < p < k(a + b_i/D_i)$ and $x_i^{\rm s} < \dfrac{a - p/k}{p - a}D_i + \dfrac{b_i}{p - a}$, provider i's cost of BO mode is less than PS mode; otherwise, the cost of PS is less than BO mode.

Proof (1) If $p < k(a + b_i/D_i)$, the difference between costs of BO mode and of Autarky mode: $\Delta C = (p/k - a)D_i - b_i < 0$ is negative. (2) If $a < p < k(a + b_i/D_i)$, BO mode and PS mode are both more cost-efficient than Autarky mode. Check the difference between costs of BO mode and of PS mode:

$$\Delta C = C_i^{\rm BO} - C_i^{\rm PS} = (p/k - a)D_i + (p - a)x_i^{\rm s} - b_i \tag{8}$$

If $x_i^{\rm s} < (a - p/k)/(p - a)D_i + b_i/(p - a)$, then $\Delta C < 0$, BO mode is more cost-efficient. If $x_i^{\rm s} > \dfrac{a - p/k}{p - a}D_i + \dfrac{b_i}{p - a}$, PS mode is more cost-efficient. ■

Propositions 2 and 3 imply that a providers' optimal choice between Autarky, BO, and PS modes depends on relationships among a, p, and $k(a + b_i/D_i)$, and relationship between $x_i^{\rm s}$ and $\dfrac{a - p/k}{p - a}D_i + \dfrac{b_i}{p - a}$. Table 2 shows all optimal modes for different conditions.

This paper does not discuss the situation in which providers who choose SO mode have no demand. Entry condition of SO mode is $p > a + b_i/x_i^{\rm s}$, which is stronger than one of PS mode.

This paper finds that optimal decisions are related to transaction cost k, fixed cost b_i, service price p, and

Table 2 Optimum decision tree for constant and identical marginal costs.

Conditions	$\varphi < a$		$a < \varphi$			
	$p \leqslant a$	$p > a$	$p \leqslant a$	$a < p < \varphi$		$p \geqslant \varphi$
				$x_i^{\rm s} \leqslant \tau$	$x_i^{\rm s} > \tau$	
Optimal mode	Autarky	PS	Autarky	BO	PS	PS

Notes: $\tau = \dfrac{a - p/k}{p - a}D_i + \dfrac{b_i}{p - a}$, $\varphi = k(a + b_i/D_i)$.

service demand D_i. When the transaction cost increases (k becomes smaller), some providers in BO mode may turn to PS or Autarky modes. If the transaction cost is high enough, no providers buy service, meaning all providers convert to Autarky mode. Service demand is another important factor impacting provider decisions. When a providers' service demand is small, it may want to buy services from others, for buying services needs no fixed costs. When service demand grows, it tends to self-provide and sell services.

4.2 Various constant marginal costs

The above decision rules for identical constant marginal costs are suitable for equally advanced providers of e-commerce services without labor inputs. However, when a new technology innovation for IT operations emerges, providers will have different exogenous technology competitive advantages in the short term. Providers adopting new technology will comprise an advanced group; the others will form a laggard group. Each group can be interpreted as a separate identical constant marginal cost market, but providers in the laggard group may buy services from providers in the advanced group.

Corollary 1 If the marginal cost of an e-commerce service is constant ($\alpha = 1$), and two levels of marginal cost exist where $a_1 < a_2$, then (1) providers with a_1 as their marginal cost do not buy services from providers with a_2 as marginal cost; (2) no trade happens between providers with a_2 as marginal cost; and (3) providers with a_2 as their marginal cost buy services from providers with a_1 only if $a_1 < p < k(a_2 + b_i/D_i)$.

Proof (1) If providers with a_1 as marginal cost buy services from providers with a_2, then we have $a_2 < p$ from Proposition 2. But if providers with a_1 as marginal cost buy services also from other providers with a_1 as marginal cost, we have $a_1 < p$. Accordingly, in order to compete with laggard providers, all advanced providers with a_1 as marginal cost will price service to satisfy the condition $a_1 < p < a_2$. As a result, laggard providers have to quit the seller's market. (2) If providers with a_2 marginal cost level need buy services, sellers with a_1 level can offer a lower price. Consequently, no trade happens between providers with a_2 level. (3) The third proposition can be easily inferred by Proposition 3. ■

From Corollary 1, this paper concludes that only the most advanced providers sell services if more than two marginal cost levels exist. All laggard providers have two choices: to buy services from the most advanced providers or self-provide services.

5 Decisions for Increasing Marginal Costs

Increasing marginal costs results in a convex curve with an inner minimum of cost model under proper conditions. As $\partial^2 f/\partial x^2 > 0$ inferred from increasing marginal costs, the service production function is

$$f_i(x) = a_i x^\alpha + b_i, \quad \alpha > 1 \tag{9}$$

Optimal solutions for every mode are presented below.

5.1 Autarky mode

In Autarky mode, $x_i^{d*} = x_i^{s*} = 0$, $C_i = a_i D_i^\alpha + b_i$.

5.2 BO mode

In BO mode, decision variable x_i^d is fixed as $x_i^d = D_i/k$, meaning $C_i = pD_i/k$.

The difference between costs of BO mode and of Autarky mode is

$$\Delta C_i = \frac{pD_i}{k} - a_i D_i^\alpha - b_i \tag{10}$$

If $\Delta C_i < 0$, we have $p < k(a_i D_i^\alpha + b_i)/D_i$.

Proposition 4 When providers have increasing marginal costs ($\alpha > 1$), if $p < k(a_i D_i^\alpha + b_i)/D_i$, BO mode is more cost-efficient than Autarky mode; otherwise, if $p \geqslant k(a_i D_i^\alpha + b_i)/D_i$, Autarky mode is more cost-efficient than BO mode.

Proof If $p < k(a_i D_i^\alpha + b_i)/D_i$, then $\Delta C_i < 0$, the cost of BO mode is less than that of Autarky mode. Otherwise, if $p \geqslant k(a_i D_i^\alpha + b_i)/D_i$, then $\Delta C_i \geqslant 0$, the cost of Autarky mode is less than the cost of BO mode. ■

5.3 PS mode

PS mode constraint is $x_i^s > 0$, but we set $x_i^s \geqslant 0$ which is a union set of the domain of both PS mode and Autarky mode. The cost function is $C_i = a_i(D_i + x_i^s)^\alpha + b_i - px_i^s$, where we have $\partial^2 C_i/(\partial x_i^s)^2 > 0$. By employing Karush-Kuhn-Tucker conditions, if $\nabla C_i(0) < 0$, that is $p > a_i \alpha D_i^{\alpha-1}$, the cost function will have an inner minimum where $\nabla C_i(x_i^{s*}) = 0$. The minimum solution is

$$x_i^{s*} = \left(\frac{p}{\alpha a_i}\right)^{\frac{1}{\alpha-1}} - D_i,\ C_i^* = \beta \frac{p^{\frac{\alpha}{\alpha-1}}}{a_i^{\frac{1}{\alpha-1}}} + b_i + pD_i \tag{11}$$

where $\beta = \dfrac{1-\alpha}{\alpha}\left(\dfrac{1}{\alpha}\right)^{\frac{1}{\alpha-1}} < 0$.

But if $\nabla C_i(0) \geqslant 0$, the cost C_i reaches minimum at $x_i^{s*} = 0$. This minimum solution is Autarky mode.

Proposition 5 When providers have increasing marginal costs ($\alpha > 1$), if $p > a_i \alpha D_i^{\alpha-1}$, PS mode is more cost-efficient than Autarky mode; otherwise, if $p \leqslant a_i \alpha D_i^{\alpha-1}$, Autarky mode is more cost-efficient than PS mode.

Proof (1) If $p > a_i \alpha D_i^{\alpha-1}$, then x_i^{s*} in Eq. (11) is optimum, meaning $C_i(x_i^{s*}) < C_i(0)$, $C_i(0)$ equals the cost of Autarky mode. The optimal cost of PS mode is less than the cost of Autarky mode. (2) If $p \leqslant a_i \alpha D_i^{\alpha-1}$, then $x_i^{s} = 0$ is optimum. The cost of Autarky mode is less than the cost of PS mode. ■

The difference between minimum cost of PS mode and cost of BO mode is

$$\Delta C_i = \frac{\beta}{a_i^{\frac{1}{\alpha-1}}} p^{\frac{\alpha}{\alpha-1}} + \frac{k-1}{k} p D_i + b_i \tag{12}$$

Proposition 6 When providers have increasing marginal costs ($\alpha > 1$), and $p > a_i \alpha D_i^{\alpha-1}$, if in Eq. (12), $\Delta C_i < 0$, then PS mode is more cost-efficient than BO mode; otherwise, if $\Delta C_i \geqslant 0$, BO mode is more cost-efficient.

Proof If $p > a_i \alpha D_i^{\alpha-1}$, PS mode has an inner minimum. Accordingly, if $\Delta C_i < 0$, the cost of PS mode is lower; otherwise, the cost of BO mode is lower. ■

5.4 PB mode

PB mode's constraint is $0 < x_i^{d} < D_i/k$, but we set $0 \leqslant x_i^{d} \leqslant D_i/k$, which is the union set of the domain of both PB mode and Autarky mode. The cost function is $C_i = a_i(D_i - k x_i^{d})^{\alpha} + b_i + p x_i^{d}$ where we have $\partial^2 C_i / (\partial x_i^{d})^2 > 0$. By employing Karush-Kuhn-Tucker conditions, this paper determines the following:

As $\nabla C_i(D_i) > 0$, if $\nabla C_i(0) < 0$, that is $p < a_i \alpha D_i^{\alpha-1}$, the cost function will have an inner minimum where $\nabla C_i(x_i^{d*}) = 0$ within $0 < x_i^{d} < D_i/k$. The minimum solution is

$$x_i^{d*} = \frac{1}{k}\left[D_i - \left(\frac{p}{\alpha a_i k}\right)^{\frac{1}{\alpha-1}}\right] \tag{13}$$

$$C_i^* = \beta \frac{p^{\frac{\alpha}{\alpha-1}}}{k^{\frac{\alpha}{\alpha-1}} a_i^{\frac{1}{\alpha-1}}} + b_i + \frac{p D_i}{k} \tag{14}$$

where $\beta = \dfrac{1-\alpha}{\alpha}\left(\dfrac{1}{\alpha}\right)^{\frac{1}{\alpha-1}} < 0$.

But if $\nabla C_i(0) \geqslant 0$, when $x_i^{d*} = 0$, $C_i^* = a_i D_i^{\alpha} + b_i$ reaches minimum. This minimum solution is Autarky mode.

Proposition 7 When providers have increasing marginal costs ($\alpha > 1$), if $p < k a_i \alpha D_i^{\alpha-1}$, PB mode is more cost-efficient than Autarky mode; otherwise if $p \geqslant k a_i \alpha D_i^{\alpha-1}$, Autarky mode is more cost-efficient than PB mode.

Proof (1) If $p < k a_i \alpha D_i^{\alpha-1}$, x_i^{d*} in Eq. (13) is optimum, that means $C_i(x_i^{d*}) < C_i(0)$, $C_i(0)$ equals the cost of Autarky mode. Therefore, the optimal cost of PB mode is less than the cost of Autarky mode. (2) If $p \geqslant k a_i \alpha D_i^{\alpha-1}$, $x_i^{d} = 0$ is the optimum of PB mode. Therefore, the cost of Autarky mode is lower than the cost of PB mode. ■

The difference between minimum cost of PB mode and cost of BO mode is

$$\Delta C_i = \beta \frac{p^{\frac{\alpha}{\alpha-1}}}{k^{\frac{\alpha}{\alpha-1}} a_i^{\frac{1}{\alpha-1}}} + b_i \tag{15}$$

If $\Delta C_i < 0$, we have $p > k a_i^{\frac{1}{\alpha}} b_i^{\frac{\alpha-1}{\alpha}} \gamma$ where $\gamma = \alpha^{\frac{1}{\alpha}} \left(\dfrac{\alpha}{\alpha-1}\right)^{\frac{\alpha-1}{\alpha}}$.

Proposition 8 When providers have increasing marginal costs ($\alpha > 1$), and $p < k a_i \alpha D_i^{\alpha-1}$, if $p > k a_i^{\frac{1}{\alpha}} b_i^{\frac{\alpha-1}{\alpha}} \gamma$, where $\gamma = \alpha^{\frac{1}{\alpha}} \left(\dfrac{\alpha}{\alpha-1}\right)^{\frac{\alpha-1}{\alpha}}$, then PB mode is more cost-efficient than BO mode; otherwise if $p \leqslant k a_i^{\frac{1}{\alpha}} b_i^{\frac{\alpha-1}{\alpha}} \gamma$, BO mode is more cost-efficient than PB mode.

Proof If $p < k a_i \alpha D_i^{\alpha-1}$, PB mode has an inner optimum. And if $p > k a_i^{\frac{1}{\alpha}} b_i^{\frac{\alpha-1}{\alpha}} \gamma$, then $\Delta C_i < 0$. This means the cost of PB mode is lower than that of BO mode. Otherwise, the cost of BO mode is lower. ■

5.5 Decision tree

By combining Propositions 4-8, this paper draws a decision tree for choosing optimal mode, shown in Table 3.

Table 3 demonstrates that a decision shift is impacted by transaction cost k, service demand D_i, service price p, and exogenous competitive advantages a_i and b_i. When the transaction cost increases, providers tend to shift from PB or BO mode to Autarky mode. When service demand increases, providers may change from PS mode to Autarky mode, or from Autarky mode to PB mode. As all decisions are sensitive to service price, when service price is low, providers tend to buy services. If service price is high, providers tend to sell services. Exogenous advantage is important factor that determines the market structure of e-commerce services. Providers with lower a_i tend to sell services, whereas ones with higher a_i tend to buy services. Providers who need to invest high amounts of

Table 3 Optimum decision tree for increasing marginal costs.

Conditions	$p < k(a_i D_i^{\alpha} + b_i)/D_i$					$p \geqslant k(a_i D_i^{\alpha} + b_i)/D_i$		
	$p < ka_i \alpha D_i^{\alpha-1}$		$ka_i \alpha D_i^{\alpha-1} \leqslant p$ and $p \leqslant a_i \alpha D_i^{\alpha-1}$	$p > a_i \alpha D_i^{\alpha-1}$		$p < ka_i \alpha D_i^{\alpha-1}$	$ka_i \alpha D_i^{\alpha-1} \leqslant p$ and $p \leqslant a_i \alpha D_i^{\alpha-1}$	$p > a_i \alpha D_i^{\alpha-1}$
	$p > \mu$	$p \leqslant \mu$		$\theta > 0$	$\theta \leqslant 0$			
Optimal mode	PB	BO			PS	PB	Autarky	PS

Notes: $\beta = \frac{1-\alpha}{\alpha}\left(\frac{1}{\alpha}\right)^{\frac{1}{\alpha-1}}$, $\gamma = \alpha^{\frac{1}{\alpha}}\left(\frac{\alpha}{\alpha-1}\right)^{\frac{\alpha-1}{\alpha}}$, $\theta = \frac{\beta}{a_i^{\frac{1}{\alpha-1}}} p^{\frac{\alpha}{\alpha-1}} + \frac{k-1}{k} pD_i + b_i$, and $\mu = ka_i^{\frac{1}{\alpha}} b_i^{\frac{\alpha-1}{\alpha}} \gamma$.

fixed cost b_i tend to choose BO mode.

6 Case Studies

6.1 12306.cn's inappropriate decision

In 2012, the Chinese Spring Festival's travel rush lasted from January 8 to February 16, with nearly 3 billion people undertaking travel during this time period (Data is from People's Daily Online. http://english.people.com.cn/90882/7704334.html). To make ticket selling more efficient and convenient, the Chinese Ministry of Railways set up a website, 12306.cn. This marked the first time that authorities introduced railway ticket booking through the internet during Spring Festival. However, rather than providing the desired efficiency and convenience, the service received an extremely high number of complaints for its slow speed and unsatisfactory service quality.

It has been reported that 12306.cn received more than 1 billion hits daily during the Chinese Spring Festival travel rush (Data is from China Daily Asia Pacific. http://www.chinadailyapac.com/article/rush-home-kicks). This substantial demand overloaded 12306.cn's information system, which had limited processing capacity. This outcome should not have been unexpected, given the site operator's decision to employ Autarky mode, as lower data processing ability to handle large amounts of traffic and limited management experience result in exogenous disadvantage of its cost function. Obviously, information technology is the main investment of online ticket booking service, having a cost function of constant marginal cost. By employing the proposed model, it can be seen that 12306.cn does not have competitive advantage. Rather, it would be better served by choosing BO mode (buying services from advanced providers) to avoid this situation. Fortunately, 12306.cn has decided to cooperate with Alipay.com to improve its e-payment service quality. The suggestion for 12306.cn derived from the proposed decision analysis is to buy a more widespread range of services until it reaches an advanced level of technology identical to its service providers.

6.2 360buy.com's logistics service

Website 360buy.com is a fast-growing Chinese e-commerce website currently on track to hit \$1.5 billion in sales for 2012[19]. The company's advantage over other e-retailers lies in its masterful logistics. 360buy.com spends a substantial sum on logistics service operations and maintenance every year, expected to reach over \$600 million in 2012. As a result, 360buy.com promises that consumers in areas covered by its logistics (always urban areas) will receive their packages within 12 hours. In addition, 360buy.com also offers its logistics infrastructure to other companies as a source of additional profit. However, 360buy.com employs third party logistics when some orders have destinations unreachable by its self-built logistics (such as remote areas).

Logistics services are classical labor-driven services, whose cost function has an increasing marginal cost. As 360buy.com has positive service demand, it has the option of four feasible modes: BO, Autarky, PS, and BS. Obviously, 360buy.com has competitive advantage in logistics within urban areas, but operates under a disadvantage in remote areas. According to this model, it is wise for 360buy.com to choose PS mode in urban areas, as this mode will enable it to not only enhance customer satisfaction, but can also theoretically reach minimum cost. However, 360buy.com should note the optimal amount of services to be sold. If this is exceeded, over-all revenue may fall from the maximum. Conversely, due to competitive disadvantages, 360buy.com chooses BO mode to provide logistics services in remote areas. 360buy.com's strategic decisions regarding logistics are perfectly in keeping with the proposed model. The model utility is upheld by the fact that 360.com has not suffered service issues, unlike the previous case, where the e-commerce site did not act in keeping with the model's best fit mode.

7 Conclusions

Decision strategy is one of management's most important issues. By focusing on e-commerce services with features of non-elastic demand and no direct revenue, this paper proposes a cost-minimizing model for analyzing optimal e-commerce service's provision modes, namely, buy, sell, autarky, self-provide and buy, and self-provide and sell. In this model, marginal cost per service is assumed to be either increasing or constant. For constant marginal costs, as there is no inner optimum solution, this paper identifies the conditions of each corner optimum by directly comparing the different modes' cost functions. For increasing marginal costs, inner and corner optimums both exist under different conditions. This paper compares the optimum of every mode pair and draws decision trees to illustrate relationships between complicated conditions and optimal decisions. For all marginal cost types, optimal decision conditions are related to four exogenous variables: transaction costs, service price, service demand, and competitive advantages (including fixed costs). The manner in which these factors impact shifts in optimal decision is the most important conclusion of our paper. Finally, this paper employs two case studies to verify the proposed model's feasibility.

This analysis is limited in its assumption of exogenous service demand and identical service quality. The equilibrium analysis will be reported in the future.

Compared with other researches of this topic, the proposed model offers several advantages. First, with regards to the reality of e-commerce companies, this paper deduces a feasible set of service provision modes that can be selected according to infra-marginal analysis methodology, which formalizes this problem in a more complete and unique way. Second, based on cost minimizing, a decision-supporting model is established after rational configuration of initial conditions and reasonable marginal cost assumptions. In addition, this model has great potential to improve e-commerce companies' provision mode selection ability. Third, this paper analyzes the impact mechanisms of the model's key factors and uses them to determine adaptive strategies for provision mode selection. Finally, two concrete case studies demonstrate the proposed model's feasibility.

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Xiao Yu received his PhD degree in control science and engineering from Tsinghua University in 2013. Currently, he is a postdoctoral fellow in the Department of Automation at Tsinghua University, China. His research interests include electronic commerce services and service supply chain.

Yueting Chai received his PhD degree in control science and engineering from Tsinghua University in 1991. Currently, he is a professor and doctoral supervisor in the Department of Automation at Tsinghua University, China. His research interests include electronic commerce, supply chain, and collaborative theory.

Yi Liu received her MEng degree in control science and engineering from Tsinghua University in 1991. Currently, she is an associate professor in the Department of Automation at Tsinghua University, China. His research interests include information system and engineering, ERP, modern logistics, and supply chain.

Hongbo Sun received his PhD degree in control science and engineering from Tsinghua University in 2011. Currently, he is a postdoctoral fellow in the Department of Automation at Tsinghua University, China. His research interest is computer simulation.