e-Commerce Game Model
Balancing Platform Service Charges with Vendor Profitability

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Abstract: One of the biggest challenges in e-commerce is to utilize data mining methods for the improvement of profitability for both platform hosts and e-commerce vendors. Taking Alibaba as an example, the more efficient method of operation is to collect hosting service fees from the vendors that use the platform. The platform defines a service fee value and the vendors can decide whether to accept or not. In this sense, it is necessary to create an analytical tool to improve and maximize the profitability of this partnership. This work proposes a dynamic in-cooperative E-Commerce Game Model (E-CGM). In E-CGM, the platform hosting company and the e-commerce vendors have their payoff functions calculated using backwards induction and their activities are simulated in a game where the goal is to achieve the biggest payoff. Taking into consideration various market conditions, E-CGM obtains the Nash equilibrium and calculates the value for which the service fee would yield the most profitable result. By comparing the data mining results obtained from a set of real data provided by Alibaba, E-CGM simulated the expected transaction volume based on a selected service fee. The results demonstrate that the proposed model using game theory is suitable for e-commerce studies and can help improve profitability for the partners of an online business model.

1 INTRODUCTION

With the development of information technology, E-commerce has fundamentally reshaped the customers' purchase behaviour through online shopping service. Online shopping attracts more and more people due to its convenience, wider range of products and time-saving benefits, and also significantly helps enterprises to reduce the cost of sales – especially for the small and medium-sized industrial groups. To cater the rising demand of e-commerce, many companies such as Amazon, eBay and Alibaba provide platforms with e-commerce infrastructure service for small businesses and individual entrepreneurs, allowing them to open online retail stores. This kind of services has significantly accelerated the growth of e-commerce, as it builds a bridge between traditional retailers and online shopping.

In 2012, online sales grew 21.1% to top $1 trillion for the first time according to the new global estimates by eMarketer (2013). With e-commerce and online shopping steadily growing up, it becomes necessary to study and improve the profit model of the platforms. Nowadays most platforms such as eBay and Amazon charge the listing fees, referral fees and variable closing fee. Apart from that, Alibaba proposed an innovation e-commerce model where the online trading platform is divided into two domains. “Taobao Marketplace” (Taobao) which is free admission, but only has grants access to basic services such as product listing; “Tmall Shopping” (Tmall) grants access to more privileges by collecting paying service fees. Alibaba guarantees the quality of its products by charging deposit from e-retailers in Tmall, this service enhances the customers’ confidence during the purchasing process.

Figure 1 shows the percentage of gross trading volume and sales of Tmall in the entire Alibaba platform (includes Taobao and Tmall) in Nov. 2012. There are 19.7% in gross trading volume and 23.6% in sales respectively over all the transactions (Alibaba, 2013). However, interesting results can be observed when we group all products in different

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price ranges. Taobao dominated transactions in the price range between ￥0.00 ~ ￥100.00 (US\$1.00≈￥6.20 in Nov. 2012), whereas Tmall observed a volume almost 25% less than the average. When the transaction price exceeds ￥100, the increase trading volume for Tmall is evident. Transaction volume and sales are both 25% more than average for the price range from ￥100.00 to ￥1000.00, and for certain price ranges it is 30% above average. This statistical result demonstrates that added services of platform can promote the transactions in e-commerce.

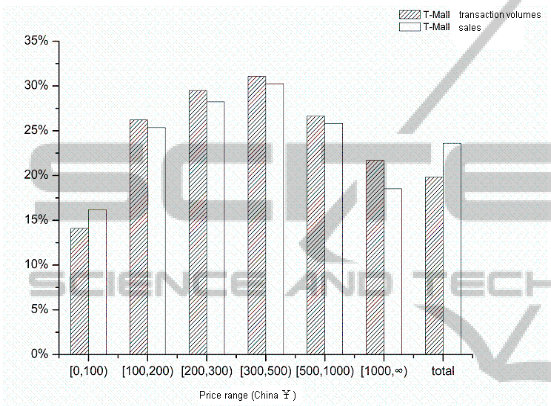

Figure 1: Percentage of Tmall in transaction volumes and sales.

This work focuses on the study of service charges of e-commerce. We propose a E-commerce Game Model (E-CGM) to calculate the best estimation for optimal service charges while taking into consideration both platform hosts and e-retailers. In E-CGM, e-commerce platform and e-retailers are modelled as players in full information dynamic game, with the payoff functions defined in a real business environment, the result, which is the Nash equilibrium of game, can be achieved by backwards-induction reasoning method.

The rest of this paper is organized as follows. Section 2 presents related work regarding relationship between traders and marketplaces in e-commerce and Leontief model in game theory. Section 3 depicts the details of E-CGM model and mathematical procedures involved in the derivation. Section 4 analyses the E-CGM and discusses Nash equilibrium. For implementation purposes, section 5 conducts an empirical study with real data collected from Alibaba e-commerce platform and makes a comparison between our results and Alibaba's current charges. An expanded model is proposed to enhance the applicability of E-CGM in section 6. Conclusion is listed in section 7 with open remarks on future work.

2 RELATED WORK

To the best of our knowledge, this work is the first attempt to calculate optimal service charges in an e-commerce platform. Although there is almost no research regarding this topic, the study of relationship between traders and marketplaces in online business provides insight to our work.

Miller and Niu (2012) viewed the marketplace selection as an N-armed bandit problem, authors assessed four reinforcement algorithms by using the JCAT double auction simulation platform. The trader profit and global allocative efficiency were discussed by comparing with the random marketplace selection. The result showed that an intelligent marketplace selection strategy is better for both trader profitability and market efficiency. Shi et al. (2010) proposed a framework for analyzing competing double auction markets that vie for traders. Authors game-theoretically analyzed the equilibrium behaviour of traders' market selection strategies and adopt evolutionary game theory to investigate how traders dynamically change their strategies. The result indicated that it is possible for the competing market to keep traders even when charging higher fees if it already has a larger market place. Also found that as the number of traders increases, this became more difficult and traders prefer the cheaper market. Sohn et al. (2009) discussed the influence of pricing policy on the trader migration. Their research demonstrated that market policy and agent trading behaviour needed to be aligned to perform effectively. They explored the implications of a biased pricing policy that be able to attract more market share and total profit.

The research of e-commerce taxation complements the growth of online business. McLure (1996) made a comprehensive and systematic study of the taxation of electronic commerce as early as 1996, where he presented economic objectives, technological constraints and tax laws in this field. Laudon and Traver (2007) analyzed Amazon's charging system, but did not propose a concrete model and the empirical study. Ahmed and Hegazi (2007) proposed a dynamic model for e-commerce taxation, which is used to derive a condition on the number of e-commerce firms to avoid market instability. Zeng et al. (2012) made a corresponding research in the Chinese e-commerce market and proposed solutions for this problem.

In our study, we take the relationship between traders and marketplaces as a game, and it fits well into the Leontief model. In Leontief's model (1946) of the relationship between a firm and a monopoly union, the union is the monopoly seller of labour to the firm that has exclusive control over wages, but the firm has exclusive control over employment. The union's utility function is $U(w, L)$, where w is the wage the union demands from the firm and L is employment. Assume that $U(w, L)$ increases in both w and L. The firm's profit function can be represented as $\pi(w, L) = R(L) - wL$, where $R(L)$ is the revenue the firm can earn if it employs L workers and makes the associated production and product-market decisions optimally.

With the study of all the above literatures, especially the Leontief's model we proposed a solution based game theory to treat the charging problem in the e-commerce platform in the next section.

3 e-COMMERCE GAME MODEL

A research model based on the game theory was developed to calculate the optimal service charges that would yield improved profit for both platform hosts and e-retailers. Section 3.1 models the e-commerce environment and specifications. Section 3.2 provides details on E-CGM, Section 3.3 analyzes briefly the Nash equilibrium of E-CGM.

3.1 Model the Environment and Specifications

The e-commerce platforms can be organized in several different architectures, each of them has a corresponding charging policy. For example, some platforms charged based on listing fees and closing fees, such as Amazon.com and eBay. Others charge a fixed service fee based on a yearly rate, such as Alibaba Tmall. In this paper, we focus on the latter environment to calculate a optimal rate that benefit both the platform and e-retailers. Here are some assumptions applied in our research.

Assumption 1: The Platform is in a Dominant Position in the Market, Raising or Setting the Amount of e-retailers will not Affect its Sales or Transaction Volumes. But More Sales or Transaction Volumes Require More e-retailers.

Suppose that the market is dominated by a certain platform in a region or a country, so raising or setting the number of e-retailers within this platform will not affect the customers' choice. It's normal in the current e-commerce market, for instances, the Alibaba in China and MercadoLivre in Brazil. But the growth of sales or transaction volumes would require more e-retailers to meet all customers' demand.

The following figure shows the e-commerce sales and the number of e-retailers in China (Cao et al., 2013). From the figure, we can see that although the number of e-retailers is small in the initial stage, it didn't have any noticeable effect on e-commerce growth. Along with the increase of e-commerce sales, the number of e-retailers has greatly increased.

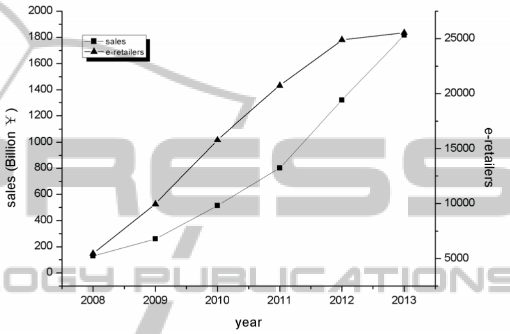

Figure 2: The e-commerce sales and the number of e-retailers (the data of 2013 is estimate value).

Assumption 2: The Qualification of an e-retailer Can be Obtained by Paying the Service Fee.

The objective of this assumption is to simplify the unnecessary restrictions. In fact, e-retailers are required to undergo tests and verifications by the platform to ensure their qualifications. But the target of this study is focus on the number of e-retailers, so the procedure of verification is not considered critical for the objective. We assume that all e-retailers will attain qualification by paying the charges.

Assumption 3: All the e-retailers Within a Platform Form a Union and There is an Even Distribution of Profit.

With this assumption, we can study the relationship between e-retailer and platform based on a macroscopic point of view. Although the result would be an estimate for individuals, it has important statistical significance to help the decision making process for both sides.

3.2 e-Commerce Game Model Design

E-CGM models the relationship between the e-commerce platform and its union of e-retailers. The platform has exclusive control over the service charges, but the union of e-retailers has exclusive control over the amount of paying e-retailers. The platform can propose a service rate and the union cannot negotiate this value. However, the union can decide on how many e-retailers will comply with such rate.

The platform's profit is related to the number of e-retailers and the service charges, so the payoff function of platform $P(\omega, L)$ can be defined as follows:

$$P(\omega, L) = \omega \times L \tag{1}$$

where ω is the value of service charges and L the number of e-retailers. We can calculate the profit of a platform depending on its service charges and the number of e-retailers. Although the platform has its cost, the marginal cost will be reduced to 0 for an increment of e-retailers. So the operational cost of the platform is omitted in its payoff function. Furthermore, this omission would not affect the result of our proposed model.

Then, we can define the payoff function of a union of e-retailers $V(\omega, L)$.

$$V(\omega, L) = \varphi(A - L) \times L - \omega \times L \tag{2}$$

where φ is the profit coefficient and is inversely proportional to the number of e-retailers (based on the assumption that the more e-retailers, the more competition in the market). $\varphi(A-L)$ is the profit of every e-retailer. A is the demand of platform for the e-retailers and the platform, it is stable during in a short period of time and can be obtained using the historical data, also considering the growth of e-commerce.

Suppose that the timing of the game is:

(1) The platform standardizes a service rate, ω.

(2) The union observes ω and then a certain number of the e-retailers choose to accept.

(3) Payoffs are $P(\omega, L)$ and $V(\omega, L)$.

3.3 Nash Equilibrium of E-CGM

The key features of this dynamic game of complete and perfect information are (**i**) the moves occur in sequence, (**ii**) all previous moves are observed before the next move is chosen, and (**iii**) the players' payoffs from each feasible combination of moves are common knowledge.

It is possible to analyze this game mostly through backward induction. First, one can characterize the best response of e-retailers' union in stage (2), $L^*(\omega)$, as an arbitrary service charge ω by the platform in stage (1). Given ω, the union of e-retailers chooses $L^*(\omega)$ to solve

$$\max_{L \geq 0} V(\omega, L) = \max_{L \geq 0} \varphi(A - L) \times L - \omega \times L \tag{3}$$

which yields

$$\partial V / \partial L = \varphi \times A - 2 \times \varphi \times L - \omega \tag{4}$$

One can obtain the relation between $L$and ω with the condition that equation (4) equals to 0.

$$L^*(\omega) = (\varphi \times A - \omega) / 2\varphi \tag{5}$$

It is a common sense that L increases while ω is reducing. However, the more e-retailers in the platform, the less profit every e-retailer will expect due to increased competition.

Next the platform's problem at stage (1) is studied. Because both the platform and the union can solve the union's second-stage problem, the platform should anticipate that the union's reaction to the service charge ω will result in a number of e-retailers $L^*(\omega)$ to comply. Therefore, the platform's problem at the first stage amounts to

$$\max_{L \geq 0} P(\omega, L^*(\omega)) = \max_{L \geq 0} (\varphi A - \omega) \times \omega / 2\varphi \tag{6}$$

Similarly, the first-order conditions of equation (6) yields

$$\omega^* = \varphi \times A / 2 \tag{7}$$

Thus, $(\omega^*, L^*(\omega))$is the backward induction outcome of this e-commerce game. From the equation (7), the service charge of a platform is dependent on the demand from e-retailer and the profit coefficient.

Figure 3 shows the indifference curve of a platform. Horizontal axis represents the number of e-retailers and vertical axis the value of the service charge. The line $L^*(\omega)$ is represent the pairs (ω, L) which satisfy the Nash equilibrium of the model. After the $L^*(\omega)$ defined, it is possible to determine the indifference profit curve of the platform which is the highest possible curve tangent with line $L^*(\omega)$. Finally, the point $(\omega^*, L^*(\omega))$ is the Nash equilibrium of this dynamic game.

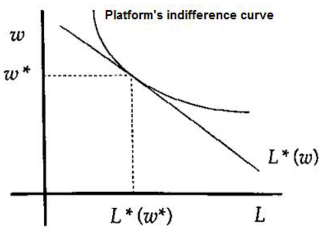

Figure 3: The indifference curve of platform.

4 ANALYSES ON THE e-COMMERCE GAME MODEL

The correctness of the model and the concept are discussed in this section.

4.1 The Service Charge ω and the Amount of E-retailers L

According to the equation (7), the charging rate is decided by the profit coefficient φ and the demand of e-retailers L in the market. In order to obtain more profit while maintaining the profit coefficient, the platform needs to increase sales to raise the capacity of e-retailers in the market. Besides of more e-retailers, the charging rate is promoted by the raise of amount of the e-retailers.

Substitute equation (7) into equation (5), the optimal amount of e-retailers is $A/4$. This means that market has a capacity of A e-retailers, by concentrating selling into $A/4$ e-retailers, the platform and these $A/4$ e-retailers both improve the profitability.

4.2 The Profit of Platform and e-Retailers

Based on the payoff functions for a platform and e-retailers, we can calculate that the profit of a platform $P(\omega^*, L^*) = \varphi A^2/8$, and for e-retailers is $V(\omega^*, L^*)= \varphi A^2/16$.

Both sides in this game have the same common interests based on these functions, and depend on profit coefficient φ and amount of e-retailers L. With a constant coefficient, the platform's aim should be to extend its market share, and the e-retailers' to provide high-quality products and good services to attract customers into making purchases.

Furthermore, the profit of the platform is twice that of the e-retailers. Suppose the profit of total market is 10, the comparison between platform and e-retailers is listed in the table below:

Table 1: The comparison of profit of e-retailers between free service and charged service.

	Charging Value	Amount of e-retailers	Profit
Free service	0	10	1
Charged service	8/3	2.5	4/3

The table 1 shows that the charged service adds the cost of e-retailers apparently, but with the decrease of e-retailers, the profit of each e-retailer will achieve a promotion (from 1 to 4/3 in the table).

5 A CASE STUDY ON ALIBABA

This work chooses Alibaba as case study to verify the E-CGM model because it is in a dominant position in China's e-market, according to the first assumption in subsection 3.1. Alibaba is a company of Internet-based commerce businesses managing online web portals. In 2012, two of Alibaba's portals together hosted \$170 billion in sales, more than competitors Amazon.com and eBay combined (Economist, 2013). Taobao Marketplace is the China's largest free-service online shopping platform, and Tmall is platform providing e-commerce opportunity at a service charge. Alibaba has the largest market share with 52.1% in B2B, B2C markets and 96.40% in C2C market (Cao et al., 2013).

The data set applied in this study includes more than 12 million transaction records from Alibaba platforms during the Nov. 2012. The transaction records have information on e-retailers, customers, price of goods etc. And more importantly, every record contains information as to which platform hosted the transaction. Through all the records, there were 10,189 e-retailers from Tmall and which equates to 3.34% of all e-retailers, but the sales for these e-retailers account for 25% of the total. Therefore, the capacity of e-retailers in Alibaba is $A= 10{,}189 \times 4$.

The sales of Alibaba during this period is ￥1.68 billion. Assuming the profit rate of e-commerce is 20% (Hoffman and Novak, 2000), the profit coefficient can be calculated by the definition

$$\begin{aligned}\varphi &= Profit / (L \times (A - L)) \\ &= (1{,}680{,}000{,}000) \times 20\% / ((3 \times 10{,}189) \times 10{,}189) \\ &\approx 1.08\end{aligned}$$

With the parameters A and φ, the profit of both the platform and e-retailers can be calculated by payoff functions respectively. Because the data set spans a month, the result of profits also reflects the transactions for a specific month.

The service charge of Alibaba can be calculated by the equation (7),

$$\omega^* = \varphi \times A / 2 = 22{,}008.24$$

from the subsection 4.1,

$$L^* = A / 4 = 10{,}189$$

The profits of the platform and e-retailers can be obtained by their payoff functions. For platform,

$$P(\omega^*, L^*) = \varphi A^2 / 8 = 224,241,957.36$$

For e-retailers,

$$V(\omega^*, L^*) = \varphi A^2 / 16 = 112,130,978.68$$

According to Alibaba's policy, every e-retailer in Tmall has to pay ￥30,000 or ￥60,000 for the service per year depend on sales. Applying the average ￥45,000 as Alibaba's service charge, we can obtain the value corresponding to a month. Then the profit of Alibaba platform is

$$\begin{aligned} P' &= \text{charging standard} \times \text{amount of e-retailers} \\ &= 10,189 \times (45,000/12) \\ &= 38,208,750.00 \end{aligned}$$

In this dataset, the 10,189 e-retailers in Tmall accomplish ￥397,393,537 in sales, so the total profit of e-retailers

$$V' = 397,393,537 \times 20\% = 79,478,707.40$$

Based on the above results, this subsection analyzes the correctness and efficiency of E-CGM comparing with the actual profits of Alibaba for the corresponding month.

According to the E-CGM, the profit of platform is 5.87 times the factual profit of Alibaba. Furthermore, the profit of e-retailers also increased 1.41 times. The profitability of platform improved significantly. As such, applying the concept of game theory, this research proposes a model that can assist both platform and e-retailers in e-commerce achieve improved profitability.

6 E-CGM EXPANDED VERSION

A real business environment is more complex and requires the more precision from any analytical results. The initial E-CGM model was proposed to simply meet a part of the various requirements, mainly focusing on the macroscopic point of view. In this section, we expand the E-CGM model and take into consideration the categorization of products in order to better simulate an actual e-commerce environment.

6.1 Payoff Functions of the Expanded E-CGM

The context of the expanded E-CGM is mostly the same as before, with the only difference being that the marketplace is assumed to have various categories of products. This change will improve the performance of the model and enhance its applicability.

Suppose there are ***K*** categories of products, which are noted as i, i = 1, 2, …, K. The service charges will then vary for e-retailers depending on the category of their products, and are noted as ω_1, ω_2, …, ω_K. And knowing the total number of e-retailers, it is possible to redefine the payoff functions of the platform and e-retailers as follows.

1) Payoff function of platform

The platform's profit is related to the number of e-retailers and the service charges for different categories, we can redefine the payoff function withω_1, ω_2, …, ω_K as follows:

$$P(\omega_1, \omega_2, ..., \omega_K, L_1, L_2, ..., L_K) = \sum_{i=1}^{K} \omega_i L_i \quad (8)$$

2) Payoff function of e-retailers

$$V(\omega_1, \omega_2, ..., \omega_K, L_1, L_2, ..., L_K) = \sum_{i=1}^{K} \ell_i (A_i - \alpha_i L_i) \alpha_i L_i - \sum_{i=1}^{K} \omega_i L_i \quad (9)$$

Because the expanded form takes into consideration different categories of products, it becomes necessary to make small changes to the parameters. The new parameters are:

A_i is the potential product demand for i.

α_i is the average number sales of i in a past time period, which can be a month, a year, etc.

L_i is the number of the e-retailers that sell i.

ℓ_i is the profit coefficient, defined as

$$\ell_i = \frac{profit}{A_i - \alpha_i L_i}$$

Comparing with the equations (1) and (2), more parameters are taken into consideration in payoff functions of (8) and (9).

6.2 Nash Equilibrium of the Expanded E-CGM

It is possible to obtain the Nash equilibrium of the expanded E-CGM through backward induction using the same steps shown in section 3.3. Because the details regarding backward induction was previously described, only the resulting Nash Equilibrium of the expanded E-CGM is shown below.

The first step is to obtain the relationship between L and ω.

$$L_i^* = \frac{\ell_i A_i \alpha_i - \omega_i}{2\ell_i \alpha_i^2} \tag{10}$$

Then, we consider two situations for ω^*: First where the platform charges all the e-retailers a standard rate, the service charges are:

$$\omega^* = \frac{1}{2} \frac{\dfrac{A_1}{\alpha_1} + \dfrac{A_2}{\alpha_2} + \ldots + \dfrac{A_K}{\alpha_K}}{\dfrac{1}{\ell_1 \alpha_1^2} + \dfrac{1}{\ell_2 \alpha_2^2} + \ldots + \dfrac{1}{\ell_K \alpha_K^2}} \tag{11}$$

On the other hands, the platform can charge the e-retailers based on the category of product they sell, ω^* will be calculated as follows:

$$\omega_i^* = \frac{\ell_i A_i \alpha_i}{2} \tag{12}$$

7 CONCLUSIONS

This work proposed a game model E-CGM to find out the optimal charging rate within an e-commerce platform. Based on the game theory, a dynamic game between two players, which are platform host and union of e-retailers, was applied to model behaviours in e-commerce. The Nash equilibrium of this game was calculated utilizing backward induction. And by applying this model in a case study evaluating a real data set of Alibaba's transaction records, Alibaba's profit was increased 5.87 times compared with the current profit value, and the profit of e-retailers increased 1.41 times. To increases the applicability of E-CGM, an expanded form is also proposed to include the variability caused by the existence of different categories of products, thus taking into consideration additional aspects of an actual business environment.

However, although the E-CGM model can improve the profitability of both the platform and e-retailers, it has its limitations. For example, the platform must dominate its market so the e-retailers have no other options and cannot negotiate service charges. Another problem is that this model greatly reduces the position of e-retailers, which could result in a more social problem. To lessen the impact of these problems, the Nash equilibrium can be analyzed and calculated based on a percentage of closing fee, which would lead to an improved service charge calculation method and minimize these limitations.

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