Efficiency and Its Influencing Factors Analysis of E-commerce based on DEA and Tobit Model

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Abstract

The study analyzes the efficiency of electronic commerce and discusses the influence factors that affect the efficiency of electronic commerce, further puts forward some suggestions to improve the efficiency. The paper uses DEA model to evaluate the technical efficiency, scale efficiency and pure technical efficiency of 60 e-commerce enterprises listed in China in 2013-2016. Furthermore, the influencing factors of the efficiency of e-commerce are analyzed by using panel data based on Tobit regression model. The results of DEA model show that the e-commerce efficiency is lower and the resource allocation of e-commerce is not optimal. The trend of efficiency value is shaped "*S*", there are two obvious inflection points in trend lines. Moreover, the efficiency of Business to Business (B2B) is almost completely close to the average of e-commerce industry in China. The efficiency of Business to

Customer (B2C) and cross border e-commerce (CBEC) are relatively higher than the average of e-commerce industry, but Online to Offline (O2O) is lower than the average. The results of Tobit regression model show that the firm size, asset turnover, shareholding ratio of maximum shareholder, industry scale and the market concentration ratio have a statistically positive relation with e-commerce efficiency. Besides, different influencing factors have different impact on different type of e-commerce. This paper indicates the direction for government to focus on the development of Business to Customer and cross-border e-commerce enterprise attribute to their efficiency is higher than the industry average. On the other hand, we provide suggestions for the managers of e-commerce enterprise to improve efficiency. Such as expending firm scale by purchasing and merger, improving service quantity to increase sales and increasing corporate governance efficiency and performance by improving the shareholding proportion of the largest shareholder.

Keywords

E-commerce; Technical efficiency ; DEA model; Tobit model

1. Introduction

The new round of scientific and technological revolution is leading to major transformation in economic structure, deeply changes the way of production and life of human, and greatly promotes the birth of new technologies, new products, new industries, new formats and new models. Recently, the rapid development of electronic commerce (EC) in China has drawn the attention of practitioners and researchers. The global influence of China's EC has been growing, and China has become the largest online retail market – the transaction volume in China now accounts for 39.2% of the global scale. Among the various EC models, such as Business to Business (B2B), Business to Customer (B2C), Customers to Customer (C2C), Online to Offline (O2O) and Cross-border e-commerce (CBEC), B2B

and B2C are the dominant forms in China's EC market, accounting for more than 90% of transaction volume.

On the other hand, with intensive competition, EC firms encounter more thorny problems, such as huge investment, excessive expansion, and low financial benefits, which result in lower efficiency (Yang, Shi, 2016). Li (2010) and C-T Bruce Ho (2011) applied Analytical Hierarchy Process and Grey Relational Analysis methods, respectively, to study the efficiency of EC, and discovered that the efficiency of EC enterprises is low. Therefore, research needs to be conducted to investigate these following issues related to China's EC: (1) why are the EC firms inefficient in booming markets such as China? (2) What internal and external factors affect the EC efficiency? (3) Are the findings on EC efficiency consistent in various modes of EC?

To answer the above questions, this paper develops empirical analyses based on the DEA-Tobit two stage model to explore the effects of internal and external factors on the EC efficiency for Chinese EC market. DEA-Tobit two stage method is an efficient integration method for analyzing efficiency and its influencing factors of enterprises or organizations (Emilyn, 2018; Chen, 2017; Liang, 2016). In the first stage of this paper, we use the DEA approach to make an empirical study on the efficiency of 60 listed EC enterprises in China, which are divided into four categories of B2B, B2C, O2O and CBEC. The technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) of all companies are measured. In the next stage, by using Tobit model with the panel data, this paper further analyzes the main factors that affect the efficiency of EC enterprises to provide strong theoretical guidance for the development of EC enterprises in China. Therefore, the main contributions of this article are as follows: firstly, we provide an insight into the causes of inefficiency for EC, which significantly helps managers to further make effective strategic measures. Secondly, the study goes a

further step that shows the applicability of the DEA-Tobit model in an empirical study and discusses the managerial implications in EC firms. Thirdly, we take into consideration to calculate the efficiency of EC at the firm level from various types including B2B, B2C, O2O and CBEC, and reveal the efficiency difference and its impacts of EC.

The reminder of this paper is arranged as follows. Section 2 provides literature review regarding efficiency evaluation. Section 3 illustrates the methodology of two-stage DEA and Tobit regression, and discusses variable selection and data collection. Section 4 describes the results of the DEA and Tobit regression respectively, and provides insightful discussion. Finally, the conclusions and suggestions are shown in Section 5.

2. Literature Review

2.1 Efficiency evaluation

Efficiency simply refers to the relationship between input and output. Efficiency evaluation was first put forward by vilfredo Pareto (1906). The so-called high efficiency means that the combination of production factors makes the output maximum when the input is unvarying or the input minimum when the output is fixed (Pakmer S, 1999). Production function is developed from western countries and it is a critical component of western economic theoretical system, which emphasizes the quantitative relationship between input and output and is used to measure efficiency. Efficiency measurement is generally divided into non-frontier methods and frontier methods. Non-frontier methods include non-parametric statistical method, group comparison method, ratio analysis method and linear programming technique. Frontier method is divided into parametric method and non-parametric method. DEA is a deputy of the non-parametric method, can measure the relative phase ratio.

The efficiency of a organization is a complicated phenomenon that usually requires at least one

single standard to describe. For policymakers, it is important to learn how the specific industry or firm can boost its multiple outputs and reduce its inputs levels by increasing efficiency. In EC industry, the website is the most important platform that helps companies to serve customers directly and beyond their competitors. Performance standard for EC need to include popularity or customer attraction, as well as other financial factors for business formats (Liu and Arnett, 2000; Liu, 2001; Phan and Stata, 2002). Although it is difficult to compare multiple criteria decision making models and tools, the comparative analysis of DEA method has been widely used as a discrete alternative decision-making tool (Saris, 2000).

2.2 Evaluation of E-commerce efficiency based on DEA Model

DEA was first proposed by Farrel in 1957 and developed as the concept of relative efficiency by A. Charnes, W.W.Cooper and E. Rhode in 1978 (Charnes A, et al., 1978). In previous literatures, there are a fraction of researches on measuring and evaluating the efficiency of EC by DEA method. For example, Wen and Billy (2003) first proposed the DEA mode to evaluate EC efficiency, and index selection is from financial and operational measures and EC specific measures, and proved that DEA model can effectively evaluate the relative efficiency of EC enterprises by empirical analysis. Kong Li (2001) pointed out that EC can improve the efficiency and effectiveness of the material procurement process in construction industry. Beck and T. wigandan (2005) collected data and compared the differences of EC efficiency between small and medium-sized manufacturing enterprises in four countries by DEA method. It was found that the EC efficiency of American and Danish enterprises is generally higher than Germany and France.

In terms of evaluation object of the EC area, most researchers pay close attention to the efficiency of website and finance. For example, some scholars mainly focus on the evaluation of the efficiency of

EC website itself and others focused on consumer satisfaction. Marsico and Levialdi (2004) establish a user-based website evaluation index system, which is a three-dimensional spatial model composed of individual, society and network. They want to evaluate EC website by this model. Chen M.M et.al (2005) and others use the information system success model to evaluate whether the information system is successful or not. Denise (2002) focused on the study of young consumers and predicted the evaluation of online consumer decisions from their personal preferences, ability and other aspects. When David M (2000) analyzing EC websites, He found that the introduction of products and services, the design of website pages and the safety of payment directly affect the consumers' desire to buy. The research on website efficiency is mainly focused on the efficiency of web site, information content and so on.

On the other hand, for financial performance, scholars usually combine with other methods to study. Wen et al. (2003) used DEA model that combined financial, operational and internet specific measures to evaluate EC performance, however, since these measures are not specific enough to represent other operational and quality-related measures of performance. Li et al. (2010) evaluated the efficiency of 6 pure EC listed firms by using the financial index, the analytic hierarchy process and the DEA model, which is a new quantitative method to evaluate and compare the performance of listed EC firms. However, the sample size is too small to be convincing. DEA model needs that the number of samples is more than twice that of the indicators. C-T Bruce Ho (2010) cited an innovative efficiency evaluation method, combining the DEA method and gray correlation Analysis to measure the relative efficiency of 69 American Internet companies, a total of 40 indicators are initially selected for the efficiency evaluation. Finally, 8 representative indicators selected by GRA are subsequently employed as the input and output indicators in the evaluation of DEA efficiency. To some extent, C-T Bruce Ho

can make up for the shortage of Li et al. These researches get the same conclusion that EC efficiency is low. However, they do not further research the influencing factors of EC efficiency. On the basis of previous studies, the research aims to explore the springhead of inefficiency for EC enterprise by DEA-Tobit model.

2.3 DEA and Tobit model applications

The DEA-Tobit two-stage model has been widely proved to explore the efficiency and its influence, such as in national public service industry, medical industry etc. Luoma K et al. (1996) evaluated the production efficiency and environmental factors of Finnish hospitals by combining DEA and Tobit. Eeva and Miika (2004) investigated cost efficiency of Finland's Public Dental Hospital is an exploratory comparison of recent trends in hospital efficiency in Ukraine, using the DEA-Tobit model to verify whether the eastern and western regions have an impact on the efficiency of Ukrainian hospitals. Li and Huan (2010) used model to analyze the railway efficiency of China. The data of these studies are usually from the statistical annual reports of each country or province.

Analysis on efficiency and influencing factors with the combination of DEA and Tobit is also employed in finance, insurance, banking and so on. A number of researches have attempted to explore the relationship between financial performance and firm's efficiency. Chen and Li (2017) selected the asset turnover and the maximum shareholding ratio as the main factors in the study of the efficiency of listed real estate companies. Ioannis Dokas et al. (2014) investigated the efficiency of the food and beverage listed firms by using DEA-Tobit model for the period 2006-2009. And they provided direct evidence that financial factors, operating cost, firm size and return on equity of total assets have significant influence on the efficiency, it gives us some inspiration. Laureti (2011) also studied that firm size has a positive influence efficiency of EC enterprise. However, another studies have obtained

different conclusions and considered that firm size do not affect the efficiency of companies. These subversive beliefs are common in the literatures on EC, which imply the importance of further verification to the EC research community. Therefore, scholars find factors such like firm size, financial performance and profitability efficiency etc. have an important influence on companies' efficiency.

As mentioned before, many studies about EC efficiency draw conclusions that the efficiency of EC is generally low. However, practically the determinant factors of inefficiency for EC companies are still unknown. In the meanwhile, another limitation is a lack of consideration of differences in the development patterns of EC when evaluating efficiency.

3. Methodology

A theoretical framework of the paper is shown in Figure 1.

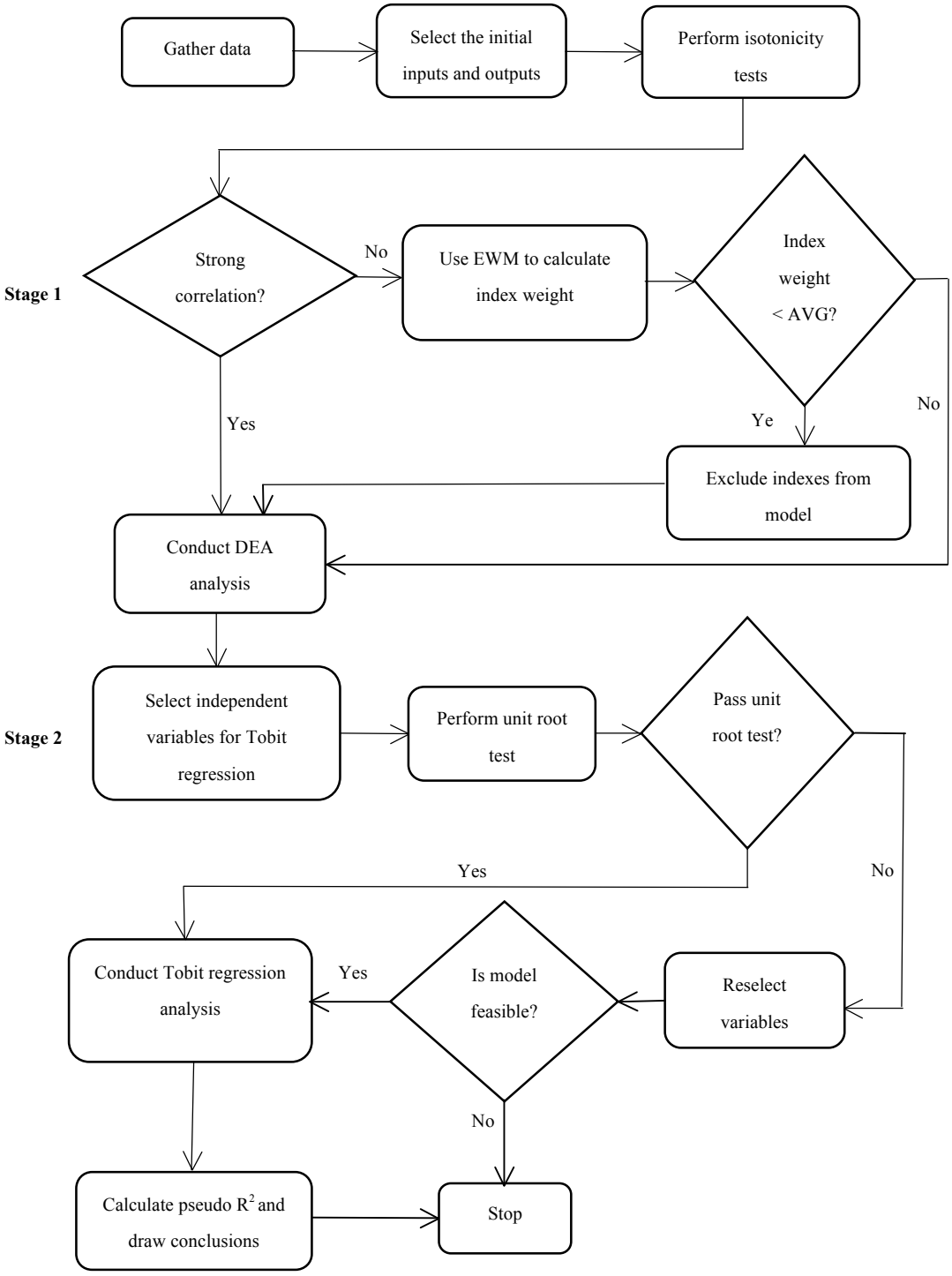

Figure 1: Two-stage frame diagram

3.1 Sample and Data Collection

The paper aims to analyze relative efficiency of EC and its influencing factors. As China's EC is experiencing remarkable development in the world, which has powerful attractions for scholars and investors both in theoretical and practical circles. There are about 1300 EC enterprise included in 100ec.cn, of which there are no more than 300 listed enterprise. Considering that EC is an emerging industry and our research focusing on the Chinese area, we removed the enterprises with incomplete data during the period of 2013-2016, and 150 listed EC enterprises are as a potential sample from 2013 to 2016 in China. In these potential samples, firstly we deleted the enterprises whose main business income comes from the manufacturing, new media and other industries, and then deleted the companies without their own trading website, finally 60 sample enterprises which are identified pure online wholesalers, retailers, or distributors. According to the classification of listed EC enterprises included by China Electronic Commerce Research Center (CECRC) which is a professional, authoritative and comprehensive EC research institutions in China. These sample companies including 48% B2B, 13.3% B2C, 16.7% O2O and 22% CBEC enterprises can basically represent the development of each market segments of EC in China.

To ensure the accuracy of empirical analysis, we collect sufficient samples and pay more attention to the availability of data. The data reflected the operation status of corporate website comes from Alexa, a website with the largest number of unified resource locator (URL). The data reflected firms' financial statements are collected from the Straight Flush Database (SFD) which is a leading comprehensive financial data, information and software services provider, and the NetEase Finance. And industry data obtained from CECRC.

3.2 Efficiency Evaluation based on DEA model

3.2.1 DEA model selection

DEA is firstly proposed by Farrel in 1957, and developed as a concept of relative efficiency by Charnes, Cooper and Rhodes in 1978 (Charnes A, et al., 1978). The method can give a full consideration to the optimal combination of multi-inputs and multi-outputs for decision-making units (DMU), so it could better reflect the characteristics of the evaluation object.

DEA included input-oriented and output-oriented models. They are the linear programming problems, and the former minimized the investments under the certain outputs, the latter maximized outputs under the fixed inputs. The importance of exploring the EC efficiency is how to promote the increase of output value and optimal firm's efficiency with the fixed financial investment. Hence the paper adopts the output-oriented model to measure EC efficiency, which has unique advantages.

We use CCR and BCC model to decompose TE into PTE and SE. The CCR model assumes that constant returns to scale (CRS), the output oriented CCR model as follows:

$$\max \varphi \qquad (1)$$

$$s.t. \quad \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{ik}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \ge \varphi y_{rk}$$

$$\lambda \ge 0,$$

$$i = 1,2\ldots,m; r = 1,2,\ldots,q; j = 1,2,\ldots,n$$

φ represents the optimal *TE* score. x_i and y_r are the known *m* inputs and *q* outputs for a specified DMU_j, and $\lambda \geqslant 0$ are the variable weights to be determined in this problem. The sum of the λ_j value is used to identify the status of RTS. Namely, $\sum_{j=1}^{n} \lambda_j = 1$ indicates the CRS; $\sum_{j=1}^{n} \lambda_j > 1$ indicates

the decreasing return to scale; $\sum_{j=1}^{n}\lambda_j < 1$ indicates the increasing return to scale.

But in actual production, many production units are not on the optimal scale. Banker et al. (1984) extended the CCR model as the following variable returns to scale (VRS) model, and TE of the CCR model contains the components of scale efficiency.

$$\begin{aligned} &\min \varphi \qquad (2)\\ &s.t. \quad \sum_{j=1}^{n}\lambda_j x_{ij} \le x_{ik}\\ &\sum_{j=1}^{n}\lambda_j y_{rj} \ge \varphi y_{rk}\\ &\sum_{j=1}^{n}\lambda_j = 1\\ &\lambda \ge 0\\ &i = 1,2,\ldots,m; r = 1,2,\ldots q; j = 1,2,\ldots,n \end{aligned}$$

φ is the optimal *TE* score. The SE can be calculated by the ratio of TE scores in Eq.(1) to PTE scores in Eq.(2) (Färe R et al, 1985).

3.2.2 DEA indicators selection

In order to achieve the scientific evaluation conclusions and obtain some useful decision-making information, we follow the some principles to screen the DEA input and output indexes (Li, 2014). Firstly, the inputs and outputs should be able to reflect the evaluation objectives and content; Secondly, there should be a strong linear correlation between inputs and outputs. So a correlation analysis must be carried out to ensure a positive relationship between inputs and outputs before efficiency calculations. Thirdly, diversity and availability should be taken into account when selecting indexes. Under the premise of fully reflecting the evaluation objectives, this paper selects measurements for the sake of availability and parsimoniousness of data with the consideration of previous researches on DEA index selection. Table 1 makes a summary of indicators selection in previous studies.

Table1 Summary of DEA input-output indicators selection

Author (s)	Methodology	Indicators	
		Input	Output
Wen et al. (2003)	DEA	Web technology investment; Corporate operating cost; Number of e-commerce staff	Profitability; Capital utilization; Capacities; Utilization; E-commerce site quality
Li, Chen (2010)	AHP-DEA	Total assets; Total indebtedness; Cash and cash equivalents; Running expenses; Asset-liability ratio; Revenue from margin operation	Operating profit; Earning per share; Net profit; Capital reserve per share; Return on equity; Total profit
C-T Bruce Ho (2011)	GRA and DEA	Total assets; Stockholder's equity; Total operating expenses; No. of employees	Revenue of scales; Profit Margin; Return on assets; Return on equity
Dimitris Balios et al. (2015)	DEA	Equity; Liabilities; Operating costs	Sales; Operating profit
Yang, Shi (2016)	DEA	Total assets; Total operating cost; Employee	Operating revenue; Market share

In generally, the labor, material and finance resources are the basic inputs for enterprises to obtain economic benefits, while the total number of employees can reflect the enterprise human resources; Material resources for EC, can be represented by the total operating expenses in the financial statements, including the enterprise's main business expenses and other business expenses; The enterprise's financial resources can choose the total assets of enterprise. Based on the above considerations and the previous studies, the paper selects three items of total assets (TA) (Li et al, 2010; C-T Bruce Ho, 2011; Yang et al., 2016;), the total operating expenditure (TOE) (Banker et al., 2002; Wen et al., 2003; C-T Bruce Ho, 2011; Dimitris Balios et al., 2015; Yang et al. 2016) and total employee number (TEN) (Wen et al.; C-T Bruce Ho, 2011; Yang et al. 2016) as input indicators.

On the other hand, the output indexes selected in this paper are total operating income (TOI)

(Chen et al., 2004; Ho and Oh, 2008; C-T Bruce Ho, 2011; Dimitris Balios et al. 2015; Yang et al. 2016), net profit (NP) (Wen et al., 2003; Chen et al., 2006; Li et al. 2010) and market share (MS) (Yang et al. 2016). The operating income is earnings before interest and taxes. The NP is the real profit, and includes the operational expenses that are excluded from gross profit. These two indicators could reflect the financial efficiency of enterprises. MS is the percentage of capture market accounted for by a specific entity (Zhang et al., 2010), and it can be calculated by the ratio of the revenue of a single enterprise to the whole market in the paper.

Table2 Descriptive statistics of input and output indexes of DEA

Indexes	Min	Max	Mean	SD
Outputs				
TOI	254.27	64919369.38	1.9675E6	8.71310E6
NP	-461203.09	1973196.28	68655.0143	3.19594E5
MS	0.00	0.55	0.0167	0.07428
Inputs				
TA	764.41	39265866.03	2.0029E6	6.90625E6
TOE	657.00	49384117.96	1.6660E6	6.82170E6
TEN	20.00	341400.00	11879.4833	46947.08439

In a word, we construct a DEA model with 3 input and 3 output indicators. Table 2 shows the basic statistics for these indicators, which shows a distinct difference between the EC enterprises. Therefore, the indexes should be screened by Isotonicity theory before the assessment of efficiency.

(1) Isotonicity analysis

A basic requirement for DEA model is the relationship between inputs and outputs should be stable. That is, increasing the value of any input under the constant of other elements should lead to an increase in the value of one output (S. H. Chung, 2008). That is called the isotonicity property of DEA. Then the correlation analysis will be conducted to ensure positive relations between inputs and outputs. If there is a negative correlation, the DEA parameters can be appropriately transformed, and one or

more parameters need to be removed from the model (Luis Daniel Otero, 2012).

The paper uses SPSS17.0 software to make Pearson correlation analysis of input and output index shown in Table 3:

Table 3 Correlation coefficient between input and output indexes of DEA

	TOI	NP	MS	TA	TOE	TEN
TOI	1					
NP	.288**	1				
MS	.958**	.286**	1			
TA	.795**	.535**	.761**	1		
TOE	.940**	.162**	.890**	.752**	1	
TEN	.936**	.246**	.967**	.745**	.869**	1

Note: **significantly correlated at level 0.01 (bilateral)

It can be seen from the theory of equal amplitude expansion, correlation coefficients are in $0.5<r<1$, which shows that there is a significant correlation between the two indicators. In Table 3, we can see that only the NP index has the lowest correlation coefficient with other input indicators. For example, the correlation coefficient $r_{25}=0.162$ between NP and TOE, and the correlation coefficient between NP and TEN is $r_{23}=0.246$. The relationship between other input indicators and output indicators showed significant correlation. Therefore, we are skeptical about the selection of net profit index, and the entropy weight method (EWM) is used to further verify it.

(2) Entropy weight method

EWM not only could be used to determine the weight of the indexes in any evaluation problem, but also it can be used to eliminate the indicators in the index system that do not contribute much to the evaluation results (Wu, 2013). In the paper, EWM is applied to eliminate the unnecessary indicators of the above six DEA indexes.

The calculation steps of entropy weight method are as follows:

① Get *m* evaluating indicator of *X-n* samples in initial matrix by samples data (X_{ij} is *i* evaluation object values of *j* index) .

Normalization: $$V_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} ; \quad (3)$$

② Calculate the characteristic specific gravity P_{ij} of index *j* correspond to the evaluation object *i* is:

$$P_{ij} = \frac{V_{ij}}{\sum_{i=1}^{m} V_{ij}} ; \quad (4)$$

③ Calculate the information entropy *Hj* of index *j*:

$$H_j = -\frac{1}{\ln(m)} * \sum_{i=1}^{m} P_{ij} * \ln P_{ij} ; \quad (5)$$

④ Calculate the coefficient of variation of index *j*. The greater d_j, the greater the amount of information provided, the greater the weight of the index:

$$d_j = 1 - H_j ; \quad (6)$$

⑤ Finally obtain the weight of index *j*：

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} . \quad (7)$$

Through the above steps, EWM between DEA inputs and outputs is obtained: The weight of TOI is 0.20763851, NP is 0.01016406, MS is 0.209722537, TA is 0.188393, TOE is 0.19857855, and t TEN is 0.185503379. The weight of NP is significantly less than other indexes, so we removed a net profit from the output index. Finally, the input indicators of DEA are TOE, TA and TEN; the output indicators are TR and MS.

3.3 Tobit regression model

Previously efficiency evaluation of EC, the influencing factors of efficiency are further explored

in the next stage. The Tobit regression model first proposed by James Tobin (1958), is known as sample selection and review (censor) model, and restricted dependent variable model. When the explanatory variable satisfies some constraint condition, the model contains two types of equations, one is discrete data model, the other is the restricted continuous variable model. In addition, the values of DEA efficiency are between 0-1 and have obvious characteristics of being truncated. If the ordinary least squares (OLS) method is used directly in regression analysis, the parameter estimation is inconsistent (Greene, 2003). At the same time, DEA is relative efficiency index rather than absolute index, so the correlation between efficiency values also makes OLS regression ineffective (Atkinson et al., 1995). Due to above consideration, in this study, a restricted dependent variable model, Tobit regression model is adopted as following:

$$Y_i^* = \alpha_1 + \alpha_2 X_i + \varepsilon_i, i = 1,2,\cdots, \ n \tag{8}$$

$$Y_i = Y_i^*, \ If \ Y_i^* > 0$$

$$Y_i = 0, \ If \ Y_i^* \le 0$$

In the above equation (8), Y_i* is a potential dependent variable, if Y_i*>0, it will be observed and the value is Y_i*; if Y_i*≤0, it will truncated at 0. X_i is an independent variable vector. α is the coefficient vector, the error term ε_i is independent and the error term ε_i is dependent on normal distribution: $u_i \sim N(0,\sigma^2)$。

3.2.1 Empirical hypothesis of influence factors

Loannis Dokasco (2014) found that operational factors such as financial leverage, operating costs, firm size and return on equity have significant effects on corporate efficiency. Chen and Li (2017) selects asset turnover and shareholding proportion of the largest shareholder as the influencing factors when studying the operating efficiency of the listed real estate companies. To sum up, this paper selects

seven factors from EC enterprise interior as independent variables, including firm size (FS), establishment time (ET), website popularity (WP), per capita output value (PCOV), operating cost (OC), asset turnover (AT), shareholding proportion of the largest shareholder (SPLS). In addition, the external influences on the enterprise efficiency have been taken into consideration as control variables, such as market concentration (MC), Gross Merchandise Volume (GMV). MC is an important quantitative index of market structure in the whole industry. It reflects the competition and monopoly degree of the market, and measures difference of the number and relative scale of enterprises. GMV refers to the output scale or operation scale of an industry, which can be expressed as gross product or output. Finally, we propose 9 empirical hypotheses of influence factors on EC efficiency:

Hypothesis 1: There is a positive correlation between firm size and EC efficiency.

Hypothesis 2: There is a positive correlation between the establishment time and EC efficiency.

Hypothesis 3: There is a positive correlation between the website popularity and EC efficiency.

Hypothesis 4: There is a positive correlation between the per capita output value and EC efficiency.

Hypothesis 5: There is a negative correlation between operating cost and EC efficiency.

Hypothesis 6: There is a positive correlation between the asset turnover and the EC efficiency.

Hypothesis 7: There is a positive correlation between the shareholding proportion of the largest shareholder and EC efficiency.

Hypothesis 8: There is a positive correlation between gross merchandise volume and EC efficiency.

Hypothesis 9: There is a positive correlation between market concentration and EC efficiency.

3.2.2 The specific Tobit regression model and variable construction

On the basis of the above hypothesis, this paper selects the influence factors as independent variables and the TE of enterprises as dependent variables, the specific Tobit model for testing the influencing factors is constructed as follows:

$$TE_{it} = C + \alpha_1 FS_{it} + \alpha_2 ET_{it} + \alpha_3 WP_{it} + \alpha_4 PCOV_{it} + \alpha_5 OC_{it} + \alpha_6 AT_{it} + \alpha_7 SPLS_{it} + \alpha_8 MC_{it} + \alpha_9 GMV_{it} + \varepsilon_{it}$$

Where, the dependent variable *TE* represents the comprehensive technical efficiency of EC listed enterprises. The independent variable *FS* is expressed by logarithm of the total assets; *ET* is time since establishment of the enterprise; *WP* is expressed by the reciprocal of rank of the website; *PCOV* is the logarithm of the per capita output value of an enterprise; *OC* is the logarithmic of operating cost, which is the sum of sales expenses, management fees and financial expenses; *AT* is the asset turnover rate; SPLS is the shareholding proportion of the largest shareholder; *MC* is expressed by the Herfindahl-Hirschman Index; *GMV* is logarithm of the size of the EC industry. *C* is a constant term, and $\partial_1, \partial_2, \partial_3, \partial_4, \partial_5, \partial_6, \partial_7, \partial_8, \partial_9$ are regression coefficients of each variable. ε_{it} is error term, *i* represents number of companies (i=1, 2, ..., 60), *t* is period (2013, 2014, 2015, 2016).

The hypothetical variables and their explanatory notes are shown in Table 4:

Table 4 Variable meaning and explanation

Variable	Symbol	Measure	Prediction direction
Firm Size	FS	The logarithmic of total assets of firm	+
Establishment Time	ET	The period from establishment to 2018	+
Website Popularity	WP	The reciprocal of global ranking of firm websites	+
Per Capita Output Value	PCOV	The ratio of main business income to total number of employees.	+
Operating Cost	OC	The logarithmic of sum of sales expenses, management expenses and financial expenses of enterprises	-
Asset Turnover	AT	Asset Turnover	+
Shareholding Proportion of the Largest Shareholder	SPLS	The shareholding ratio of maximum shareholder	+
Market Concentration	MC	The quadratic sum of the total income or the	+

		percentage of total assets of each market competition in an industry	
Gross Merchandise Volume	GMV	The logarithmic of annual transactions of EC industry	+

4. Empirical results

4.1 Efficiency evaluation

Under the assumptions of VRS, the output-oriented BCC model is processed with data of inputs and outputs by using Deap2.1 software. The calculations (mean, max, min, standard deviation) of TE, PTE, SE for each category of EC enterprises from 2013 to 2016 are shown in Table 5. Figure 2 reflects the trend of TE, PTE and SE of EC in China in 2013-2016 years.

Table 5: The statistics of TE, PTE, SE of B2B, B2C, O2O and CBEC from 2013 to 2016

		2013			2014			2015			2016		
		TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
B2B companies be listed	Mean	0.484	0.569	0.894	0.771	0.822	0.946	0.504	0.671	0.764	0.563	0.722	0.813
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Min	0.018	0.201	0.018	0.105	0.105	0.397	0.101	0.102	0.124	0.080	0.134	0.080
	Sd.	0.227	0.250	0.201	0.213	0.209	0.123	0.275	0.270	0.235	0.285	0.287	0.246
B2C companies be listed	Mean	0.628	0.744	0.877	0.814	0.908	0.903	0.521	0.837	0.663	0.583	0.822	0.725
	Max	1.000	1.000	1.000	0.999	1.000	0.999	0.688	1.000	0.960	0.853	1.000	0.961
	Min	0.262	0.274	0.639	0.578	0.582	0.785	0.207	0.439	0.207	0.115	0.422	0.153
	Sd.	0.210	0.254	0.119	0.110	0.137	0.075	0.153	0.205	0.224	0.243	0.186	0.282
O2O companies be listed	Mean	0.551	0.582	0.959	0.772	0.809	0.946	0.317	0.548	0.653	0.454	0.582	0.832
	Max	1.000	1.000	1.000	1.000	1.000	1.000	0.629	1.000	0.969	1.000	1.000	1.000
	Min	0.147	0.147	0.826	0.411	0.441	0.669	0.084	0.278	0.130	0.214	0.228	0.473
	Sd.	0.256	0.279	0.061	0.206	0.179	0.096	0.148	0.263	0.278	0.220	0.297	0.183
CBEC companies be listed	Mean	0.520	0.673	0.821	0.811	0.836	0.971	0.604	0.740	0.842	0.562	0.655	0.886
	Max	0.922	1.000	1.000	1.000	1.000	1.000	0.815	1.000	0.997	0.987	1.000	0.999
	Min	0.109	0.235	0.109	0.476	0.517	0.791	0.358	0.464	0.358	0.132	0.271	0.132
	Sd.	0.264	0.260	0.296	0.148	0.149	0.056	0.130	0.147	0.191	0.241	0.223	0.228
Industry Mean		0.522	0.616	0.887	0.786	0.835	0.945	0.497	0.688	0.749	0.547	0.698	0.82

TE reflects the comprehensive utilization efficiency of enterprise resources, and PTE is mainly to measure the technology and management level of enterprise, and SE reflects whether the current resource inputs reaches the best scale or not (Li, 2014). TE =PTE * SE. From table 5, we can see that max value of TE, PTE, SE in every category are approaching 1, it reflects there are some completely efficient firms in each category. On the other hand, the average comprehensive efficiency values of 60 listed EC enterprises in 2013-2016 are 0.522, 0.786, 0.497 and 0.547 respectively, which shows that the EC efficiency is lower and the resource allocation of EC enterprises is not optimal. The conclusion is consistent with Wen (2003), Li (2010) and C-T Bruce Ho et al. (2011).

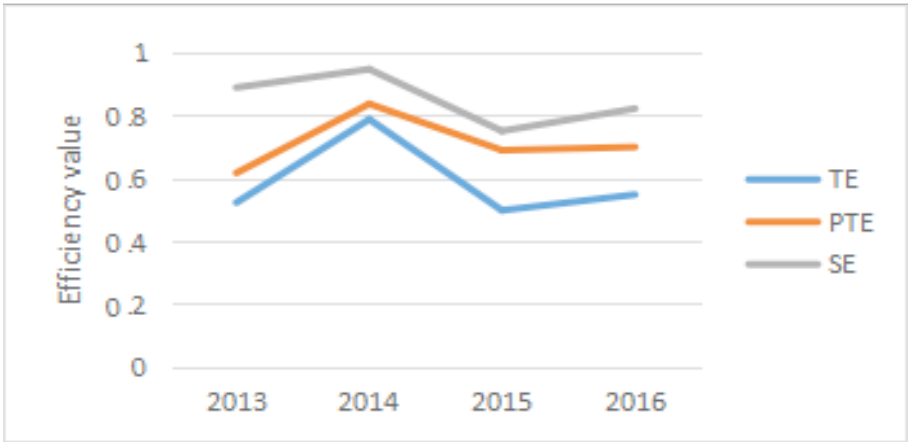

Figure2: The technical efficiency trend of e-commerce in China

Figure 2 shows the trend of TE, PTE and SE efficiency shaped *"S"*. There are two obvious inflection points in trend lines, one of maximum TE value is nearly 0.8 in 2014, the other of minimum TE value is lower than 0.5 in 2015. It can be seen that the efficiency of EC increased rapidly from 2013 to 2014, however, the efficiency values of EC declined quickly from 2014 to 2015, and then increased slowly. Meanwhile, we can see the lower TE of EC visibly attribute to lower PTE and SE, and PTE is slightly lower than SE, implying that EC companies need to improve their management level and technological innovation capabilities.

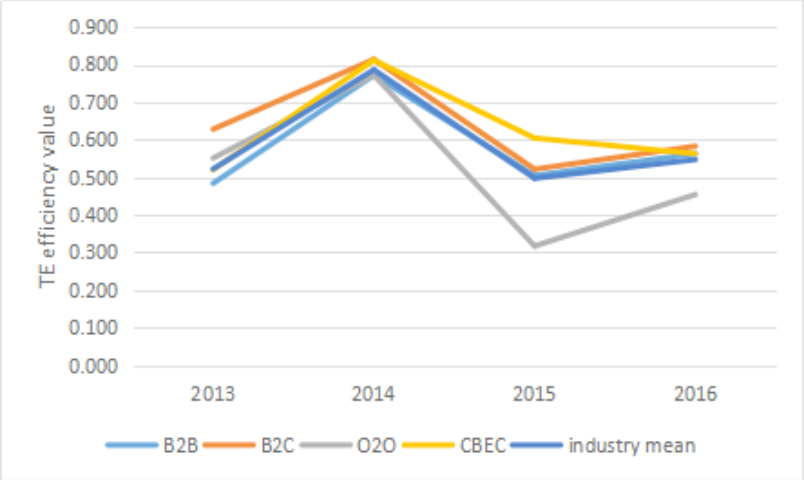

Figure 3 TE of four major types of e-commerce enterprises

The TE of B2B, B2C, O2O and CBEC from 2013 to 2016 is shown in Fig 3. We can see that the overall trend of TE for different modes is roughly same, but the B2B efficiency is almost completely close to the average efficiency of EC, because BTB dominates the EC industry in China, accounts for about 75% of the industry according to the data of 100EC.CN. The efficiency of B2C and CBEC are significantly higher than average, and O2O is lower than the EC industry average. According to the China EC report, the total value of EC transactions in 2016 amounted to 26.1 trillion yuan, while the O2O transaction is only 0.7 trillion yuan, the proportion is less than 3%. Overall, the efficiency of B2C and CBEC is high. B2C plays an important role in EC market. Alibaba, which holds half of the market share of the proprietary B2B market in 2014, and JingDong, which occupies 60% of the B2B market, went public successively. Therefore, nine of the top 10 enterprises in the domestic B2C field were already listed companies. In addition, an emerging field, CEBC, is also developing rapidly. The CEBC transaction is 6.7 trillion yuan in 2016, which occupies 25.7% of the whole EC market.

4.2 Influencing factors analysis

The Tobit regression analysis is conducted to capture the factors of efficiency by Eviews5.0 software. The efficiency value of sample enterprise obtained from the above is taken as the dependent

variable, while the FS, ET, WP, PCOV, OC, AT and SPLS are as the independent variable, and MC, GMV are as the control variables. Table 6 shows the descriptive statistics of variables in Tobit regression analysis.

Table 6 Descriptive statistical analysis of variables in Tobit model

Variables	N	Minimum	Maximum	Mean	SD
Dependent variable					
TE	240	0.02	1	0.588	0.26173
Independent variable					
FS	240	75.59	57386136.42	2.0029E6	7.35491E6
ET	240	2	47	11.3333	7.67688
WP	240	10	69870467	9.1764E6	1.75059E7
PCOV	240	0.03	4612.35	215.3335	530.62633
OC	240	31.37	28931893.59	525299.8967	2.69771E6
AT	240	0.04	31.98	2.0918	3.69774
SPLS	240	0.02	0.91	0.3907	0.22432
Control variable					
MC	240	0.30	0.35	0.3299	0.02010
GMV	240	1.02E9	2.30E10	6.7900E9	9.36551E9

In order to further ensure the stability of the panel data, unit root of Tobit regression data is examined by Eviews5.1 software. In table 7, two methods of PP-Fisher Chi-square and Hadri Z-stat shows that the data has no unit root, which proves the stability of the panel data.

Table 7 Results of Unit root test

Method	Statistic	Prob	Cross-sections	Obs
Null: Unit root (assumes individual unit root process)				
PP - Fisher Chi-square	308.431	0.0000**	59	177
Null: No unit root (assumes common unit root process)				
Hadri Z-stat	8.40713	0.0000**	60	240

** Probabilities for Fisher tests are computed using an asympotic Chi -square distribution. All other tests assume asymptotic normality.

Table 8 presents the estimation results. It can be seen that R-squared is about 0.31, and Log likelihood is about 25.81, which has certain credibility and the regression result is more accurate. Moreover, in order to further reveal whether there are differences in the influencing factors of efficiency under the different modes of EC, we also process the Tobit regression according to the four modes of B2B, B2C, O2O and CBEC. Table 9 shows the results under the different models. The R-squared and Log likelihood are also acceptable.

Table 8. Tobit regression results of all sample enterprises

Variables	coefficient	Std. Error	Z-statistic	Prob.
FS	0.045756	0.023796	1.922861	0.0545*
ET	-0.001623	0.002284	-0.710479	0.4774
WP	-0.511206	0.936208	-0.546039	0.5850
PCOV	0.001807	0.007611	0.237454	0.8123
OC	0.017428	0.026352	0.661349	0.5084
AT	0.028982	0.003942	7.351229	0.0000***
SPLS	0.232740	0.081273	2.863676	0.0042***
MC	6.660560	1.497915	4.446555	0.0000***
GMV	0.154045	0.055168	2.792281	0.0052***
Constant	-3.471330	0.995325	-3.487636	0.0005
R-squared	0.306974	Mean dependent var	0.587992	
Adjusted R-squared	0.276711	S.D. dependent var	0.261730	
S.E. of regression	0.222592	Akaike info criterion	-0.123408	
Sum squared resid	11.34629	Schwarz criterion	0.036121	
Log likelihood	25.80901	Hannan-Quinn criter.	-0.059130	
Avg. log likelihood	0.107538			

Note: *** Significant at the 0.01 level; ** Significant at the 0.05 level; * Significant at the 0.1 level.

The results show that FS, AT, MSSR, MCR and ECIS have significantly significant impacts on TE of EC enterprises. The coefficients for the impacts of them are all positive, which is consistent with the hypothesis 1, 6, 7, 8, 9. However, the variables of ET, PEW, PCOV and OC are insignificant, which does not conform to the hypothesis 2, 3, 4, 5, and the details are as follows:

(1) The variable of FS has a statistically significant and the coefficient is about 0.046, which shows that the larger FS, the more efficiency it will be in the current market situation. It is consistent with *hypothesis 1*, so expanding the scale of enterprises is one of the effective ways to improve the EC efficiency.

(2) The coefficient of AT is about 0.029, which is positively correlated with the EC efficiency, and that is consistent with *hypothesis 6*. The larger AT, the management quality and utilization efficiency of all assets is higher. Therefore, the EC enterprise can improve the efficiency by increasing sales revenue or decreasing total assets.

(3) The coefficient of SPLS is about 0.233, which has a significant positive correlation with EC efficiency, and that is consistent with *hypothesis 7*. The larger SPLS, the more centralized the decision-making is, the higher efficiency is achieved. Therefore, EC enterprises can choose the linear structure management mode, which is helpful to improve efficiency.

(4) The coefficient of MC is about 6.661, the higher the MC, the stronger the market dominance of large enterprises. At present, the leading EC market players, such as Amazon, Alibaba, JingDong, and other large enterprises occupy a very large market share of EC, and their TE is also very high, which is consistent with *hypothesis 8*.

(5) The coefficient of GMV is about 0.154, which has a significant positive correlation with the EC efficiency. With the expansion of EC market scale, the market demand continues to increase, and the efficiency of EC enterprises increases gradually. That is consistent with *hypothesis 9*.

Table 9. Tobit regression results of four different modes of EC

Variable	B2B	B2C	O2O	CBEC
FS	0.104303	-0.098936	-0.504684	0.097553
	(0.0083)***	(0.3374)	(0.0000)***	(0.2213)

ET	-0.002335	-0.013585	0.036892	0.000628
	(0.4507)	(0.2458)	(0.0000)***	(0.9110)
WP	137.5673	2.193370	413.3300	-2918.488
	(0.2003)	(0.2808)	(0.0002)***	(0.0126)**
PCOV	-0.003017	0.193461	0.824638	0.073250
	(0.6993)	(0.1228)	(0.0000)***	(0.1085)
OC	-0.070977	0.107114	0.360399	-0.008550
	(0.2708)	(0.4043)	(0.0000)***	(0.9128)
AT	0.026489	0.028047	-0.097007	0.108795
	(0.0000)***	(0.5024)	(0.0607)*	(0.0000)***
SPLS	0.271290	-0.403537	0.015071	0.447509
	(0.0209)**	(0.2585)	(0.9228)	(0.0402)**
MC	0.148662	0.221088	0.229538	0.044071
	(0.0552)*	(0.0599)*	(0.0183)**	(0.6245)
GMV	5.532484	9.409972	18.67089	4.070938
	(0.0089)***	(0.0051)***	(0.0000)***	(0.1130)
Constant	-2.998427	-4.832387	-8.564596	-1.947842
	(0.0328)**	(0.0328)**	(0.0000)***	(0.2432)
R-squared	0.411417	0.465922	0.694734	0.536783
Log likelihood	15.39241	13.70070	19.09555	22.01631

Note: *** Significant at the 0.01 level; ** Significant at the 0.05 level; * Significant at the 0.1 level.

On the other hand, Table 9 provides some interesting facts that 9 explanatory variables have different effects on the efficiency of four different EC modes, including B2B, B2C, O2O and CBEC.

B2B is an important area in EC, it's influencing factors of efficiency are completely consistent with EC, and hypothesis 1, 6, 7, 8, 9 are supported in B2B. For B2C, only external factors do influence the efficiency, and internal factors still to be further explored. For O2O, the variables of ET, WP, PCOV, OC, MC, GMV have positive correlated with efficiency and FS, AT have negative correlated with efficiency, SPLS is insignificant. FS, OC and AT have statistical significance with efficiency of O2O enterprise, but they do not in line with our hypothesis. Therefore hypothesis 2, 3, 4, 8, 9 are supported. We guess one of the reasons for the results is the expansion of FS plays a limited role in improving efficiency in O2O market, and the other reason is the OC has a positive effect on the

efficiency within a certain range. For CBEC, hypothesis 6, 7 are supported, WP has negatively correlated with efficiency, it's consistent with the original hypothesis 3.

5. Conclusions and recommendations

Firstly, this paper estimates the efficiency of four different EC modes by using DEA-BCC model during the period of 2013 to 2016. The results show that TE of EC industry is obviously lower and waver, the trend of TE, PTE and SE efficiency is shaped *"S"*, and efficiency values reached maximum in 2014 and decreased to minimum in 2015. In addition, the TE value of B2B is closest to EC industry average, B2C and CBEC are higher than average, O2O is less than average.

Secondly, the Tobit regression model is constructed to determine the underlying influencing factors of EC efficiency. The findings indicate that firm size, asset turnover, shareholding proportion of the largest shareholder, market concentration and gross merchandise volume have statistically significantly impacts on TE for total EC industry, and *hypothesis 1, 6, 7, 8, 9* are supported. At the same time, different types of EC have significant difference on influencing factors of EC efficiency: firm size, asset turnover, shareholding proportion of the largest shareholder, market concentration and gross merchandise volume have positive effect on B2B efficiency; market concentration and gross merchandise volume have positive effect on B2C efficiency; establishment time, website popularity, per capita output value, operating cost, market concentration and gross merchandise volume have positive effect on O2O efficiency, and firm size, asset turnover have negative effect on O2O efficiency; asset turnover and shareholding proportion of the largest shareholder have positive effect on CBEC efficiency, website popularity has a significant negative effect on CBEC efficiency.

In view of these conclusions, the paper gives the following management implications:

On the one hand, from the perspective of EC industry, the government should focus more on the

development of B2C and CBEC, because their TE value is higher than average efficiency value of EC industry.

On the other hand, combined with Tobit regression results, our policy recommendations from the perspective of enterprise interior are as follows:

(1) B2B enterprises can promote their efficiency by means of acquisition, merger and so on. Strengthening internal management, speeding up the circulation of funds and preventing unreasonable capital from occupying pressure are effective measures for enterprise to improve asset turnover. Increasing corporate governance efficiency and performance by improving the shareholding proportion of the largest shareholder.

(2) O2O enterprises should not rely on burning money to attract consumers' attention, but innovate product by optimizing the platform service so as to ensure sound development and lengthen establishment time, and avoid bankruptcy crises. They also can focus on improving website popularity, such as increasing technology investment, improving product quality and connecting accurately information between business and customers. Other measures such as increasing overhead expenditure to strengthening internal management and taping their potential, actively generating income to improve per capita output value. What the important point for O2O is to prevent the scale expansion of malicious competition.

(3) CBEC enterprises should not only pay attention to improve asset turnover and shareholding proportion of the largest shareholder, but also seek the third party trading platform to increase sales channels. For example, the Suning not only has it's own trading website (Suning.com), it also has official flagship store in TMALL.com.

6. Limitation and further research

Compared with the previous studies on EC efficiency, the study discusses the efficiency of EC and its influencing factors based on DEA-Tobit two stage model, which makes up for the deficiencies of the existing research, but also provide theoretical reference for EC enterprises of different modes. In particular, the results of this study are not only of interest to individual EC enterprises, but also to policy makers for formulating industrial guidelines in China, and it is of great significance to the development of EC in the word.

At the same time, there are still limitations worth further study. Firstly, although the sample can meet the basic requirements of DEA efficiency evaluation in this study, the data is limited in China, a comparative study with other countries such as America, Japan and Korea will be considered in the next research. Secondly, although the article prudently chooses DEA evaluation index system and puts forward the empirical hypotheses of influencing factors based on previous studies and the characteristics of e-commerce, there are still some potential factors existed, such as research expenses, websites visitors, and public praise etc. Thirdly, the paper provides an insight on impact on EC efficiency, but it is still lack of in-depth analysis of direct and indirect impacts, this will be another key point of the further study.

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Author introduction

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