Operational Efficiency Evaluation of Chinese Logistics Enterprises Based on DEA Model

Yuwen Liang*

School of Economics and Finance, South China University of Technology, Guangzhou 510006, China

*Corresponding author: 201930442018@mail.edu.cn

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Abstract: In China's logistics industry competition, logistics enterprises need more effective operational strategies. Therefore, this paper will evaluate the operational efficiency of the largest logistics enterprises in China, and make suggestions on this basis to improve the operational efficiency. This paper uses the DEA model to derive the technical efficiency, pure technical efficiency, and scale efficiency to evaluate the operational efficiency of logistics enterprises. The result of this paper is that the technical efficiency of Chinese logistics enterprises is at the middle level, the pure technical efficiency is at a relatively high level, and the scale efficiency is at the medium level. So this paper puts forward the following suggestions: transforming to supply chain services, optimizing the allocation of resources, expanding the scale of enterprises, developing logistics human resources, developing advanced technology. This paper believes that the DEA model can be used to evaluate the operational efficiency of Chinese logistics enterprises. After obtaining the data from Chinese logistics enterprises from 2015 to 2020, this paper obtains the technical efficiency, pure technical efficiency, and scale efficiency of each enterprise every year through the MaxDEA program. Then the obtained results are used to analyze the operational efficiency of the Chinese logistics industry and enterprises. Finally, this paper puts forward suggestions for the development of Chinese logistics enterprises.

1. Introduction

1.1 Background

The logistics industry is one of the strategic industries with fundamental significance and occupies a leading position in the national economy. In recent years, China's logistics industry has developed rapidly. According to statistics from the China Federation of Logistics and Purchasing, China's total logistics volume increased steadily from 2011 to 2019. By 2019, the total amount of national logistics has reached 298.0 trillion yuan, a cumulative increase of 5.9% from 2018, and more than 15.84 billion yuan in 2011. The growth rate of the total amount of the logistics industry far exceeds the growth rate of GDP in the same period and has become the "booster" and "accelerator" of the national economic development. However, compared with developed countries, China's logistics enterprises still have high investment and low efficiency. Therefore, this paper studies the operation efficiency of the logistics enterprises in China to find out the reasons of the inefficiency and put forward reasonable suggestions to promote the development of the logistics industry.

1.2 Related Research

In 1978, Cooper et al. used the knowledge of mathematics, operation research, mathematical economics and management to develop an efficient, and scientific linear planning method, proposing the most basic data envelopment analysis (DEA) model, namely Charnes-Cooper-Rhodes (CCR) model [1]. The DEA model can be used to evaluate the efficiency of enterprises. Since incomplete competition, policy restrictions, economic environment and other factors may make it difficult for enterprises to operate at the most ideal scale, Banker et al proposed the CCR model in 1984 to account for variable remuneration of scale, the Banker-Charnes-Cooper (BBC) model [2].

Zhou et al. used data envelopment analysis (DEA) to measure Chinese ten leading 3PLs, comparing previous periods and the operational efficiency of their competitors. They found that sharp declines in domestic traffic activity and the slow adaptation of state-owned enterprise into a more market-based economy led to a decrease in the efficiency of some 3PLs in China. Sales opportunities and technical expertise levels can affect the operational efficiency of 3PL, while the size of 3PL has no direct impact on 3PL performance [3]. Min and Joo illustrate the effectiveness of the DEA in measuring the competitiveness of third-party logistics services by using examples of America's leading third-party logistics companies. Min and Joo found that the strength of the 3PL service performance and the breadth of the different 3PL services were somewhat correlated to the long-term financial strength of the 3PLs [4]. Liu et al. collected the operation data of eighteen power grid enterprises in Henan Province, China and used data envelopment analysis (DEA) to evaluate the operation efficiency of Henan power grid. Based on an analysis of the problems existing in these grid companies, Liu et al. identified key factors limiting increased operating efficiency [5]. Ji and Shan used the data envelopment analysis (DEA) method to evaluate the total factor productivity of Chinese listed maritime companies in 2016-2018. The results show that the total factor productivity of these enterprises is at a good level in recent years, and the main reason for the inefficiency of shipping enterprises is the low technical efficiency and low management efficiency. The technology and management level should be improved [6].

Abbasi and Kaviani adopt three uncertain data envelopment analysis (DEA) models, including fuzzy DEA (FDEA), imprecise DEA (IDEA) and Grey DEA, propose an operational performance evaluation framework that analyzes and ranks organizations according to the effectiveness of their operational strategies. Ranking results help enterprises compare to their competitors and then make appropriate strategic and operational decisions to improve operational efficiency [7]. Wang et al. uses a three-stage DEA to evaluate the port efficiency of the two most competitive shipping centers in Northeast Asia, the Shanghai and Busan ports, respectively. In addition, the effects of port pollutant emissions on the respective input variables were examined. The results show that both overscale and pollutant emissions are important factors leading to the insufficient efficiency of Shanghai ports [8]. Chen et al. uses principal component analysis-data envelopment analysis (PCA-DEA) integrated model to establish the key indicators and system framework for logistics efficiency research, and to evaluate the operational efficiency of iron ore logistics in Bohai Bay ports in China [9]. Jiang et al. used super-efficiency slacks-based measure DEA (SBM-DEA) model to build an index system based on a green perspective and evaluate the sustainability efficiency of Chinese listed companies [10]. Pan et al. uses super efficiency DEA to obtain performance data, and then uses the LMBP neural network to fit the enterprise performance to obtain a quantitative model of performance evaluation. Pan et al. found that the BP neural network based on the LM algorithm can accurately and effectively evaluate the performance of the reverse logistics enterprises. They give the direction of the performance improvement of reverse logistics enterprises, to provide a reasonable optimization direction for enterprises [11]. Hu et al. calculated the return on scale and average efficiency of the 15 ASEAN airlines between 2010-2014. The decomposition input efficiency of ASEAN airlines is calculated by comparing the target with the actual input. The results showed that ASEAN Airlines had the lowest aircraft efficiency, good operating cost efficiency, and available seat efficiency is the best [12].

1.3 Objective

This paper is to study the operation efficiency of Chinese logistics enterprises.The efficiency evaluation of enterprises refers to the use of operation research principle and mathematical statistical methods, select a specific index system, refer to the standards set, compare with certain procedures, through qualitative and quantitative analysis, to make an objective judgment on the business effect of enterprises.From a macro perspective, we can understand the comprehensive level of a country's third-party logistics industry, and provide methods and basis for formulating the development strategies and policies of the national logistics industry.On the micro level, it can reflect the scale, actual management level and resource allocation of third-party logistics enterprises, and then promote the effective and reasonable allocation of resources of logistics enterprises; but also conducive to find their own

problems, and provide management decision information for enterprises, so as to improve their comprehensive strength and market competitiveness.

2. MEthod

2.1 Data Envelopment Analysis Model

The data envelopment analysis (DEA) method was proposed by A. Charnes and W. W. Cooper in 1978 [1]. It is a linear programming technique, and is a commonly used non-parametric efficiency analysis method which based on comparison among evaluated objects [6]. The DEA method uses multi-input indicators and multi-output indicators to evaluate the input-output efficiency, which is an effective method to evaluate the efficiency of the same type of multi-input and multi-output decision-making units (DMUs) [5]. The DEA method was first used for performance evaluation in non-profit organizations as well as in the public sector. Later, the DEA method was widely used in various fields due to the advantages of data processing, including the banking industry, logistics industry, performance evaluation, resource allocation and so on.

Currently, there are two commonly used DEA models, namely, the Charnes-Cooper-Rhodes (CCR) models and the Banker-Charnes-Cooper (BBC) models [11]. The CCR model is used to measure the total efficiency when assuming Constant Returns to Scale (CRS), and the BBC model is used to measure the pure technical efficiency and scale efficiency when assuming Variable Returns to Scale (VRS) [6]. In this paper, due to evaluate the comprehensive efficiency, the pure technical efficiency and the scale efficiency, the BBC model will be selected to analyze the DMUs.

The DEA-BBC model is:

$$\min[\theta - \varepsilon(e^{-T}s^{-} + e^{+T}s^{+})] \tag{1}$$

$$\sum_{j=1}^{n} X_j\lambda_j + s^{-} = \theta X_0 \tag{2}$$

$$\sum_{j=1}^{n} Y_j\lambda_j + s^{+} = Y_0 \tag{3}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{4}$$

$$\lambda \geq 0, j = 1, 2, \cdots, n;\ s^{+} \geq 0;\ s^{-} \geq 0 \tag{5}$$

Among them, X_{ij}, Y_{ij} indicate the i th input indicators and the r th output indicators of the j th decision-making unit. The s^{-}, s^{+} are relaxation variables, representing input redundancy and insufficient output, respectively. θ is the efficiency value of the decision unit, if $\theta_0 = 1$, $s_i^{-0} = 0$, $s_i^{+0} = 0$, DMU_0 is valid DEA and at the management edge; if $\theta_0 = 0$ only, DMU_0 is invalid DEA [8].

2.2 Indicator Selection

Table 1. Operating efficiency input and output index system of Chinese logistics enterprises

Indicator type	Indicator name	Variable
Input Indicators	fixed net asset value	X_1
	employee salary	X_2
	operating costs	X_3
	management expenses	X_4
Output Indicators	net profit	Y

The index system is the basic basis for the operation efficiency evaluation of logistics enterprises, so when using the DEA model to evaluate the operation efficiency of logistics enterprises, the selection of input variables and output variables is very important. This paper uses different companies as

decision-making units for production. Through literature review, it is found that the input variable and the output variable of the efficiency evaluation of logistics enterprises have not formed a unified standard. Therefore, this paper selects indicators based on the principles of representativeness, systematization, independence, relevance, and feasibility. The selection of logistics industry input index is divided into asset investment and cost investment. Costs can also be subdivided into logistics costs, labor costs, and administrative costs. Therefore, this article selects fixed net asset value, employee salary, operating costs and management expenses as the input variable. The ultimate goal of logistics enterprises is to obtain economic benefits, so this paper chooses net profit as the output variable.

2.3 Data Source

The data comes from Choice Financial Terminal (professional financial data analysis and investment management software under Oriental Wealth), Straight Flush (free online stock and securities trading analysis software), Netease Finance (financial mobile phone software), and Big Wisdom (securities information platform). The data set used in this paper includes data from YUNDA Express, SF Holding, STO Express, YTO Express, Deppon Express between 2015 and 2020.

3. Results

In this paper, the BCC-DEA model in MaxDEA software is used to analyze the efficiency of five logistics enterprises in China from 2015-2020 to obtain technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE), respectively, as shown in Table 2. According to the average efficiency score of each year, the line chart Figure 1 was drawn, showing the trend of the overall efficiency change of the Chinese logistics industry.

Technical efficiency refers to the ability to achieve maximum output under a given input factor, which reflects the effective utilization of resources. Since $TE = PTE \times SE$, it shows that the technical efficiency is jointly affected by the pure technical efficiency and the scale efficiency. Pure technical efficiency is brought by the enterprise system and management level, and it is a production affected by factors such as management and technology. PTE=1, indicating that the use of the input resources is effective at the current technical level. The higher the pure technical efficiency score, the higher the reasonable degree of resource allocation. Scale efficiency is the production efficiency affected by the enterprise scale factors, which reflects the degree of enterprise from the optimal state. SE=1, indicating the scale efficiency is effective. If SE <1, the scale efficiency is invalid, which is divided into two cases: increasing returns to scale and decreasing returns to scale

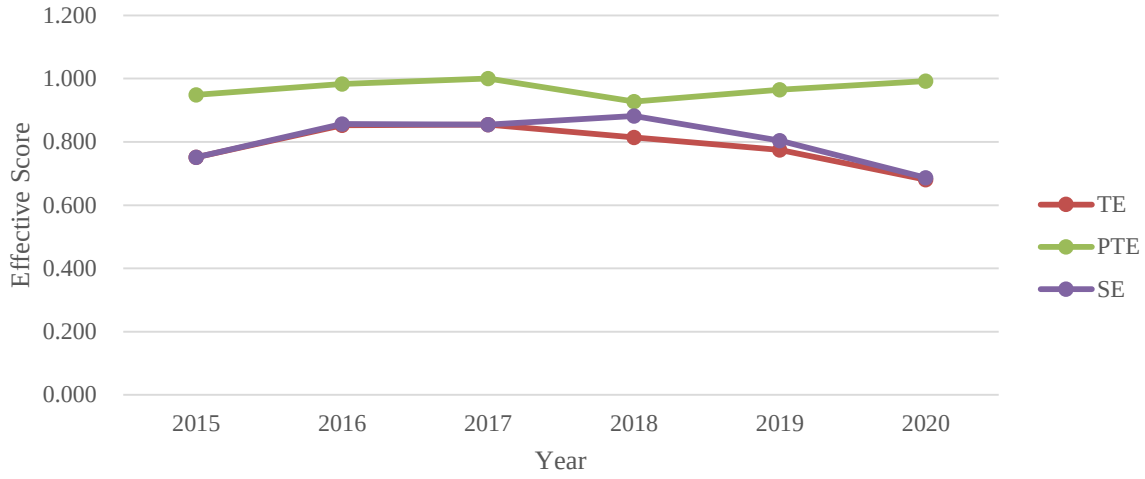

Figure. 1 Average efficiency score of Chinese logistics enterprises

3.1 Technical efficiency analysis

According to Table 2, the average technical efficiency of five Chinese logistics enterprises is 0.788, indicating that the efficiency of listed Chinese logistics enterprises is at a medium and high level. There are unreasonable aspects of the input and output portfolio, leading to the low resource utilization rate, and there is still 21.2% room for improvement. According to Figure 1, the average technical efficiency trend of Chinese logistics enterprises in the past five years has increased first and then reduced, which is a bad development trend. This shows that in the past two years, Chinese logistics enterprises have become worse and worse in resource utilization, which need to be improved.

From the perspective of a single enterprise, YUNDA Express and SF Holding have reached $TE = 1$ for more than four years, which have achieved DEA effectiveness. It shows that these two companies both have relatively reasonable input-output portfolios and have been at the forefront of technological efficiency for many years. The average technical efficiency of YTO Express is 0.869, which is also at a relatively high level. The technical efficiency trend of YTO Express is reduced first and then increased, and reached 1 at 2020, showing a good development trend. However, Deppon Express and STO Express show a very low technical efficiency. Both companies are less than 50% technically efficient in most years, meaning that they have a lot of room to improve.

3.2 Pure technical efficiency analysis

As shown in Table 2, the average pure technical efficiency of the five Chinese logistics enterprises is 0.970, indicating that the efficiency of the Chinese listed logistics enterprises is at a very high level. It shows that the management and technical level of Chinese logistics enterprises is high, and almost reach DEA effective. The service innovation input-output structure of these enterprises is in line with the development process of enterprises, and realizes the optimal allocation of logistics service innovation resources.

Analysising different enterprises, Deppon Express, STO Express, SF Holding and YUNDA Express have almost reached PTE=1 in most years, which means that they are DEA effective most of the time. And YTO Express shows a different trend from other logistics companies. Its pure technical efficiency and technical efficiency show the same trend, which are reduced first and then increased. That means YTO Express, while briefly lagging behind others, quickly improved and kept up with others.

3.3 Scale efficiency analysis

Table 2 indicates that the average scale efficiency of five Chinese logistics enterprises is 0.806, showing that the efficiency of listed Chinese logistics enterprises is at a medium and high level. China's logistics enterprises are not far from the optimal scale state, but the overall scale efficiency is lower than the technical efficiency. This means that the main reason for the insufficient overall high efficiency of Chinese logistics enterprises is the low scale efficiency rather than the low technical efficiency, that is, enterprise excessive waste of resources or unreasonable business scale problem. Except for SF Express Holding in 2018, all the enterprises that do not reach constant returns to scale are in a state of increasing returns to scale. This shows that the enterprise scale of China's logistics enterprises is relatively small in general.

Looking at the data of each enterprise respectively, SF Holding, YTO Express and YUNDA Express have almost reached PTE> 0.9 in most years. The three enterprises have higher scale efficiency than other enterprises, and do not need to increase their scale and investment. Deppon Express only achieved scale efficiency DEA effective in 2015, with an average scale efficiency of 0.39 in other years, and did not show a growth trend. From 2016 to 2018, STO Express achieved DEA scale efficiency DEA effective, but the average scale efficiency in six years was only 0.65, and showed a trend of raising first and reducing later

Table. 2 Efficiency score of Chinese logistics enterprises

Year	DMU	Efficiency Score			
		Technical Efficiency Score (**TE**)	Pure Technical Efficiency Score (**PTE**)	Scale Efficiency Score (**SE**)	Returns To Scale (**RTS**)
2015	Deppon Express	1.000	1.000	1.000	-
	STO Express	0.000	0.744	0.000	Increasing
	SF Holding	0.757	1.000	0.757	Increasing
	YTO Express	1.000	1.000	1.000	-
	YUNDA Express	1.000	1.000	1.000	-
	(Average)	(0.752)	(0.949)	(0.752)	-
2016	Deppon Express	0.262	0.919	0.286	Increasing
	STO Express	1.000	1.000	1.000	-
	SF Holding	1.000	1.000	1.000	-
	YTO Express	1.000	1.000	1.000	-
	YUNDA Express	1.000	1.000	1.000	-
	(Average)	(0.852)	(0.984)	(0.857)	-
2017	Deppon Express	0.355	1.000	0.355	Increasing
	STO Express	1.000	1.000	1.000	-
	SF Holding	1.000	1.000	1.000	-
	YTO Express	0.918	1.000	0.918	Increasing
	YUNDA Express	1.000	1.000	1.000	--
	(Average)	(0.855)	(1.000)	(0.855)	-
2018	Deppon Express	0.492	1.000	0.492	Increasing
	STO Express	1.000	1.000	1.000	--
	SF Holding	0.977	1.000	0.977	Decreasing
	YTO Express	0.600	0.637	0.942	Increasing
	YUNDA Express	1.000	1.000	1.000	-
	(Average)	(0.814)	(0.927)	(0.882)	-
2019	Deppon Express	0.301	1.000	0.301	Increasing
	STO Express	0.873	1.000	0.873	Increasing
	SF Holding	1.000	1.000	1.000	-
	YTO Express	0.699	0.827	0.845	Increasing
	YUNDA Express	1.000	1.000	1.000	-
	(Average)	(0.774)	(0.965)	(0.804)	-
2020	Deppon Express	0.540	1.000	0.540	Increasing
	STO Express	0.053	1.000	0.053	Increasing
	SF Holding	1.000	1.000	1.000	-
	YTO Express	1.000	1.000	1.000	-
	YUNDA Express	0.807	0.963	0.839	Increasing
	(Average)	(0.680)	(0.993)	(0.686)	-
	(Ensemble Average)	(0.788)	(0.970)	(0.806)	-

4. Discussion

4.1 Transforming to supply chain services

Now China's logistics industry is developing rapidly, and the competition is becoming more and more fierce. What the user needs is not a single service, but a comprehensive service. Innovation and application in the supply chain are conducive to strengthening the effective connection of each link from production to consumption, and reducing the operation and transaction costs of enterprises, so that enterprises can obtain higher operational efficiency.

According to news reports, since the beginning of 2019, SF Holding, STO Express, Deppon Express and other logistics enterprises have set up new companies to expand diversified businesses and established a supply chain system. It can be seen that logistics enterprises will seek transformation and upgrading to achieve higher operation efficiency, and the transformation into a supply chain service provider will be a natural development process.

4.2 Optimizing the allocation of resources

The unreasonable allocation of internal resources leads to a lot of cost input, but the output is not enough transformed into benefits. In the research above, some enterprises' pure technical efficiency cannot reach the DEA effective. Therefore, enterprises should consider improving the allocation of internal resources, such as speeding up the construction of enterprise internal information platform, realizing the transparency of enterprise internal resources, calling of materials more efficient, reducing the idle equipment, waste of resources, backlog of goods, warehouse occupation and so on. More reasonable resource allocation can promote more efficient operation within enterprises, which can improve the operating efficiency of enterprises.

4.3 Expanding the scale of enterprises

The data results above show that the scale efficiency of most logistics enterprises is DEA invalid, leading to the low technical efficiency score of these enterprises. Logistics enterprises in their own conditions permit, can formulate scientific strategic planning, consider the appropriate expansion or reduce the scale of the enterprise, reduce the investment redundancy due to excessive expansion, or reduce the waste of resource allocation caused by too small scale. While improving the scale, enterprises should also consider the allocation and optimization of internal resources, so as to lay a good foundation for the subsequent development in advance, and to avoid causing new problems.

4.4 Developing logistics human resources

As the provider of new service types of logistics enterprises, and the founder of service innovation information of logistics enterprises, human resources are an important internal resource for logistics enterprises for service innovation. Therefore, the comprehensive quality of human resources has a positive impact on the operation efficiency of logistics enterprises.

Logistics enterprises should adjust the distribution of human resources according to the specific situation of the enterprise to realize the efficient allocation of human resources. In addition, enterprises need to improve the reward system, and set up employee salaries according to the employees' ability, so that the investment in human resources can obtain the corresponding and efficient output. At the same time, enterprises should also improve the training mechanism, establish a clear management target, so as to improve the enterprise management level.

4.5 Developing advanced technology

Although it can be seen from the data above, the pure technical efficiency of Chinese logistics enterprises is already very high. However, with the development of the logistics industry, logistics enterprises need to constantly update new technologies to deal with the increasingly fierce competition. In the future, logistics enterprises should actively introduce modern logistics facilities and equipment to improve the integration and automation level of logistics enterprises. In addition, logistics enterprises should continue to introduce the Internet of Vehicles, the Internet of Things, cloud

computing and other technologies, to further integrate information technology with the logistics industry, and to improve the technical efficiency level of enterprises.

5. Discussion

In this paper, the DEA-BBC model is selected to evaluate the operating efficiency of Chinese logistics enterprises. First, this paper establishes an index system to evaluate the operating efficiency of enterprises, that is, fixed net asset value, employee salary, operating cost and management expenses as the input variable, and net profit as the output variable. This paper then collects data from five Chinese logistics companies from 2015 to 2020. Next, this paper inputs the processed data into the MaxDEA software, yielding the technical efficiency, pure technical efficiency, and scale efficiency of each enterprise each year. Since then, this paper analyzes the results derived from the efficiency data. Finally, this paper puts forward suggestions conducive to the development of China's logistics industry and enterprises.

The result of this paper is that the technical efficiency of Chinese logistics enterprises is in medium level, the pure technical efficiency is relatively high, and the scale efficiency is in medium level. SF Holding and YUNDA Express are the two logistics enterprises with the most efficient operation efficiency, which means they can effectively and reasonably allocate resources. And Deppon Express, STO Express, YTO Express need to correct their own problems, change the decision-making information of enterprises, so as to improve the operation efficiency of enterprises.

This paper puts forward the suggestions that Chinese logistics enterprises can transform to supply chain services, optimize their own resource allocation, expand the scale of enterprises, develop logistics human resources, and develop advanced technology.

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