Comparison and Evaluation of the Input-Output Efficiency of Listed Chinese Logistics Companies Based on CCR-DEA

Zhenling Chen[1], Yi Chen[1], Xine Peng[1], Hong Tao[1], Linmin Yang[1], Lin Xue[2,*]

[1]Economics and Management School, Minjiang University, Fuzhou, China

[2]Committee of Communist Youth League, Minjiang University, Fuzhou, China

*Corresponding Author: Lin Xue

Keywords: Input-output efficiency; CCR-DEA mode; listed logistics companies

Abstract: Based on the 2017-2019 panel data on 20 Chinese logistics companies, this paper analyzes the key factors affecting their input-output efficiency from dimensions such as overall technical efficiency (OTE), pure technical efficiency (PTE) and scale efficiency. Data analysis reveals that although the overall input-output efficiency of listed Chinese logistics companies has been edging down over the years, there remains room for improvement. Among the four industries of port operation, warehousing, transportation and express delivery, the express delivery industry stands out by dint of its top-ranking OTE, PTE and scale efficiency. Port operation companies and road transport companies have experienced continuous decline in PTE for three consecutive years. In order to improve the output efficiency, logistics companies must place more emphasis on the improvement of PTE by attaching importance to technology R&D and innovation, and on the other hand improve their core competitiveness by beefing up their logistics functions.

1. Introduction

Over the past years, China, with its logistics industry undergoing booming development, has become the world's most influential logistics power. According to statistics, in 2019, China's total value of social logistics goods reached RMB 298 trillion, up 5.9%, and total social logistics costs reached RMB 14.6 trillion, up 7.3%. Among others, the total value of industrial logistics products was RMB 269.6 trillion, up 5.7%, and the total retail sales of consumer goods went up by 8%.

Presently, there are a variety of methods to study the business performance of listed logistics companies, and there are also a wealth of research results. Employing the CCR-DEA and BCC-DEA models, Deng Xueping and Wang Xu took fixed assets, gross payroll of employees and operating costs as input variables and total profit before tax as output variable to perform an empirical analysis of the technical efficiency and scale efficiency of the 28 logistics companies listed on Shanghai Stock Exchange, Shenzhen Stock Exchange and Hong Kong Stock Exchange, concluding that the logistics companies do not have significant economies of scale and suggesting that the thriving growth of a logistics company lies in technological improvements and service quality [1]. Cao Guo, Liu Lu and Ying Kewei used Bayesian stochastic frontier theory to conduct an empirical analysis of the production efficiency of 32 logistics companies specialized in air transport, port operations, ocean transport, inland water transport and key logistics operations, to take descriptive statistics of their main business costs, net fixed assets and gross payroll, and to carry out efficiency analysis of inputs and outputs, concluding that logistics companies must adjust the input of production factors as per their actual internal conditions in order to avoid the wasting of resources [2]. Selecting 12 listed logistics companies with marketing activities, Ma Xiaonan took sales staff, advertising expenses and marketing expenses as the input indicators and the growth rate of main business incomes, return on net assets, inventory turnover rate and account receivable turnover rate as the output indicators to conduct an empirical analysis, concluding that there is no significant correlation between the size of the logistics company and the performance of marketing activities, and that the return to scale of marketing performance is diminishing [3]. Selecting 18 listed logistics companies, Qin Yao and Qian Wuyong constructed a dynamic multi-indicator gray

  DOI: 10.25236/ecemis.2021.011

target decision model based on panel data to carry out an empirical analysis, urging logistics companies to continuously pursue IT-enabled, networked and intelligence-centric development, to attach importance to infrastructure construction, and to improve operating performance [4]. Cheng Dayou et al. employed the analytic hierarchy process (AHP) to evaluate the performance scores of 30 listed Chinese logistics companies [5]. Zhang Ruirui et al. established an evaluation indicator system for 24 listed logistics companies through principal component analysis (PCA) [6].

The existing research results have provided strong methodological support for the scientific evaluation of logistics companies' business performance, as well as insightful enlightenment for the applied research into the evaluation of logistics companies. Still, existing studies have the following limitations: 1) Most of the data selected for the evaluation of logistics companies were data of a certain year, making it challenging to compare the differences between different years; 2) When selecting indicators, some methods ignored the objective data relating to the evaluation targets, which could easily lead to unscientific calculation results; and 3) In studies targeting the above-mentioned logistics companies, the selection of research targets only took into account the commonality of companies in this industry, but ignored their individuality, and the research data collected so far are not the latest data on the operation of logistics enterprises. In view of all these, this paper uses the CCR-DEA model to examine the investment efficiency of listed Chinese logistics companies, thereby effectively avoiding the various drawbacks of the existing research methods.

Based on the 2017-2019 panel data on 20 listed Chinese logistics companies, this paper uses the CCR-DEA model to evaluate their business performance.

2. Model and Methodology

DEA is a non-parametric method that can be used to evaluate the production and operation of companies, and this paper uses the CCR-DEA model to compare and evaluate the listed logistics companies based on the 2017-2019 panel data. Amid the comparison and evaluation of listed logistics companies, inputs are easier to control than outputs. Therefore, while using the CCR model to evaluate and compare the DMUs, the paper opts for the input-oriented DEA model, which mainly uses convex analysis and linear programming as tools and applies mathematical programming model to calculate and compares the relative efficiency between DMUs, thereby evaluating the targets of evaluation. The basic idea is: there are n DMUi (i = 1, 2 … n), and the input and output vectors of DMUi are:

$$\begin{aligned} A_i &= (a_{1i}, a_{2i}, \cdots, a_{mi})T \geq 0, i = 1,2,\cdots,n \\ B_i &= (b_{1i}, b_{2i}, \cdots, b_{si})T \geq 0, i = 1,2,\cdots,n \end{aligned} \tag{1}$$

Where: m denotes the number of input indicators and s denotes the number of output indicators. We will build the following basic CCR model:

$$\min \theta = \theta_0$$

$$\text{s.t} \begin{cases} \sum_{i=1}^{n} A_j \lambda_j + s^- = \theta B_0 \\ \sum_{i=1}^{n} B_j \lambda_j - s^+ = B_0 \\ \lambda \geq 0, \quad j = 1,2,\cdots,n; s^+ \geq 0, s^- \geq 0 \end{cases} \tag{2}$$

Suppose the optimal solution is λ*, s* - and θ* and it's needed to determine the validity of DEA. If s* -= 0, s* + = 0, θ* = 1, then DMUi is valid for DEA; if s * — ≠ 0, s* + ≠ 0, θ* ≠ 1, then DMUi is weakly valid for DEA; if θ* ≤ 1, then DMUi is not valid for DEA.

3. Empirical Research

3.1 Establishment of Evaluation Indicators and Data Sources

In order to ensure that the evaluation indicator system is scientific, systematic, and easily available, the input indicators are net fixed assets, total operating cost, gross payroll and overhead

expenses, while the output indicators are net profit and total operating income. The data come from the 2017-2019 annual reports released by 20 listed logistics companies on eastmoney.com. Among them, the total operating cost and the net fixed assets respectively represent the production & operating costs and the tangible assets of the enterprise, corresponding to capital inputs, while the overhead expenses and the gross payroll correspond to the labor inputs. Total operating income and net profit respectively represent the output level and output efficiency.

3.2 Input-output Efficiency Analysis

3.2.1 Overall technical efficiency analysis

The overall technical efficiency (OTE) is used to measure how efficient the resources allocated by the enterprise are used. A value of 1 means that the input-output efficiency of the DMU is valid for DEA [7]. The results are shown in Table 1. Specifically, the TE values of Lianyungang Port, STO Express, SF Express, CMST and CRCC are all 1 for three consecutive years, indicating that these listed companies boast efficient allocation of input resources and outstanding operating efficiency. With a sophisticated collection and distribution system, Lianyungang Port has developed a comprehensive network of sea, land and air transportation, and has given full play to the interactive, complementary and competitive effects of industrial clusters. STO Express has brought into shape a comprehensive and unimpeded self-operated express delivery network across the country, and basically achieved the full coverage of express delivery in Jiangsu, Zhejiang and Shanghai. Over the past years, in addition to providing cross-regional express delivery services, STO Express also managed to expand into new operations, with operating income and net profit climbing up greatly. Yunda Express saw the quickest increase in TE value from 2017 to 2019. Leveraging automation and intelligent technologies to save costs and improve the efficiency of express logistics system, Yunda Express strives to rev up the intelligent transformation of the logistics industry and to improve its own input-output efficiency. Similarly, Yantian Port, Jinzhou Port and Xinning Logistics have also taken targeted measures to improve operating efficiency. On the whole, roughly 60% of logistics companies have a TE value reaching 0.8 or above, showing that a majority of logistics companies boast higher operating efficiency, yet there are also a considerable proportion of companies who are in need of further improvement. Winbase, Nanjing Port and Yantian Port ranked the bottom for three consecutive years, with the TE value of Yantian Port falling below 0.4 for three consecutive years.

By category, the three-year average OTE values of road transport companies, express delivery companies, port operation companies and warehousing companies stand at 0.858, 0.921, 0.701 and 0.766 respectively. The increasingly popularity of e-commerce across the globe has spurred the burgeoning development of road transportation and express delivery industries, which in turn pushed up the average OTE of road transportation and express delivery companies. Still, the OTE values of road transportation companies were 0.886, 0.872 and 0.815 respectively in the three years, edging down year by year. This must be brought to our attention; those of express delivery companies were 0.972, 0.802 and 0.987 respectively in the three years, exhibiting an upward trend in spite of minor fluctuations; and those of port operation companies and warehousing companies were also going down year by year. Fortunately, the decline is slowing down with a positive sign.

Table 1 Overall Technical Efficiency (2017-2019)

TE	2017	TE	2018	TE	2019
Zhongyuan Expressway	1	Lianyungang Port	1	Lianyungang Port	1
ZTO Express	1	STO Express	1	STO Express	1
CRCC	1	SF Express	1	SF Express	1
CMST	1	Wuhu Port	1	Yunda Express	1
YTO Express	1	YTO Express	1	CMST	1
Wuhu Port	1	CMST	1	CRCC	1
SF Express	1	CRCC	1	Zhongyuan	1

				Expressway	
STO Express	1	Zhongyuan Expressway	0.976	ZTO Express	0.970
Lianyungang Port	1	Freetrade Science & Technology	0.911	YTO Express	0.965
Aucksun	1	Aucksun	0.897	Wuhu Port	0.870
China Southern	0.982	COSCO Shipping	0.837	Jinzhou Port	0.862
Yunda Express	0.861	Yunda Express	0.812	Aucksun	0.827
Sinotrans	0.801	Sinotrans	0.799	Sinotrans	0.780
Freetrade Science & Technology	0.779	Jinzhou Port	0.779	Freetrade Science & Technology	0.756
Jinzhou Port	0.763	China Southern	0.747	China Southern	0.686
COSCO Shipping	0.646	Winbase	0.499	Xinning Logistics	0.649
Xinning Logistics	0.619	Xinning Logistics	0.479	COSCO Shipping	0.611
Winbase	0.568	Nanjing Port	0.422	Winbase	0.499
Nanjing Port	0.522	Yantian Port	0.292	Nanjing Port	0.375
Yantian Port	0.271	ZTO Express	0.200	Yantian Port	0.354

3.2.2 Pure technical efficiency analysis

Pure technical efficiency (PTE) can be used to analyze the production efficiency of the DMU's inputs affected by technical factors at the optimal scale. A value of 1 indicates that the resource allocation is effective under the current technology level [7]. The results are shown in Table 2. The PTE values of a majority of logistics companies are above 0.8, indicating that the main reason why the OTE of these listed companies has not been valid for DEA is that their PTE is yet to improve. Winbase, Lianyungang Port, STO Express, SF Express, CMST, CRCC, ZTO Express and Zhongyuan Expressway all saw their PTE standing at 1 for three consecutive years. Yantian Port underwent a significant decline in PTE due to its poor technical performance and the insufficient number of containers, while Xinning Logistics witnessed a sharp rise in PTE thanks to its quick technical improvement. Moreover, the PTE of Yantian Port has remained low for three consecutive years.

By category, the three-year average OTE values of road transport companies, express delivery companies, port operation companies and warehousing companies stand at 0.884, 0.977, 0.817 and 0.937 respectively, with express delivery companies spearheading the growth. The PTE values of express delivery companies were 0.972、0.964 and 0.995 respectively in the three years, going down first and then rebounding quickly. The OTE values of warehousing companies were 0.914, 0.944 and 0.951 respectively in the three years, with their PTE embarking on an upward track. The PTE values of port operation and road transportation companies were 0.873, 0.817 and 0.760 respectively and 0.912, 0.897 and 0.843 respectively in the three years. Since the outbreak of the global financial crisis in 2008, the global economy and trade have suffered a major blow, which has had a significant impact on port operation companies whose main business is container and cargo handling, thereby leading to the gradual decline of their average PTE. This must be brought to our attention.

Table 2 Pure Technical Efficiency (2017-2019)

PTE	2017	PTE	2018	PTE	2019
Zhongyuan Expressway	1	Freetrade Science & Technology	1	Winbase	1
ZTO Express	1	Winbase	1	Lianyungang Port	1
CRCC	1	Lianyungang Port	1	STO Express	1
China	1	STO Express	1	SF Express	1

Southern					
CMST	1	SF Express	1	Xinning Logistics	1
YTO Express	1	Wuhu Port	1	Yunda Express	1
Yantian Port	1	YTO Express	1	CMST	1
Wuhu Port	1	CMST	1	CRCC	1
SF Express	1	CRCC	1	ZTO Express	1
STO Express	1	ZTO Express	1	Zhongyuan Expressway	1
Lianyungang Port	1	Zhongyuan Expressway	1	YTO Express	0.974
Winbase	1	Aucksun	0.956	Aucksun	0.885
Aucksun	1	COSCO Shipping	0.840	Wuhu Port	0.884
Yunda Express	0.861	China Southern	0.833	Jinzhou Port	0.876
Sinotrans	0.831	Yunda Express	0.821	Freetrade Science & Technology	0.871
Freetrade Science & Technology	0.789	Sinotrans	0.811	Sinotrans	0.783
Xinning Logistics	0.783	Jinzhou Port	0.801	COSCO Shipping	0.731
Jinzhou Port	0.764	Xinning Logistics	0.763	China Southern	0.699
COSCO Shipping	0.728	Yantian Port	0.681	Nanjing Port	0.522
Nanjing Port	0.599	Nanjing Port	0.603	Yantian Port	0.521

3.2.3 Scale efficiency analysis

Scale efficiency is used to measure the input-output efficiency of an enterprise affected by scale. When the scale efficiency of DMU is 1, it indicates that the overall input-output technical inefficiency of the DMU at the current scale might result from inadequate PTE. The results are shown in Table 3, according to which the scale efficiency of a majority of listed logistics companies is above 0.9, meaning that most of them are close to the frontier of scale efficiency. Relatively speaking, companies such as Yantian Port, Xinning Logistics and Winbase rank relatively low, indicating that the resources invested by these companies have not been used rationally, leading to the wasting of the same. It is worth mentioning that Yantian Port has continuously improved its scale efficiency for three consecutive years as a result of its sustained efforts to expand the market share, to deepen the scale and management of the industrial chain and to improve the scale and performance of the company, thereby gradually enabling the efficient utilization the resources invested. Winbase has been vigorously consolidating its main business of warehousing and at the same time actively expanding into upstream and downstream sectors to seek new profit opportunities. Meanwhile, Winbase is also actively developing businesses such as financial leasing, commercial factoring, supply chain finance, etc., and gradually expanding operations other regions and upstream and downstream industrial chains, thereby continuously increasing its profitability and shoring up its long-term stable development.

By category, the three-year average scale efficiency values of road transportation companies, express delivery companies, port operation companies and warehousing companies stand at 0.967, 0.943, 0.780 and 0.818 respectively. The average scale efficiency values of road transportation companies and express delivery companies are relatively higher, while those of warehousing companies rank relatively low, promising great potential for growth. The average scale efficiency values of road transportation companies were 0.966, 0.971 and 0.962 respectively in the three years,

while those of express delivery companies were 0.943, 0.838 and 0.992 respectively in the three years.

Table 3 Scale Efficiency (2017-2019)

SE	2017	SE	2018	SE	2019
Aucksun	1	Lianyungang Port	1	Lianyungang Port	1
Lianyungang Port	1	STO Express	1	STO Express	1
STO Express	1	SF Express	1	SF Express	1
SF Express	1	Wuhu Port	1	Yunda Express	1
Wuhu Port	1	YTO Express	1	CMST	1
YTO Express	1	CMST	1	CRCC	1
CMST	1	CRCC	1	Zhongyuan Expressway	1
CRCC	1	COSCO Shipping	0.996	Sinotrans	0.996
ZTO Express	1	Yunda Express	0.988	YTO Express	0.991
Zhongyuan Expressway	1	Sinotrans	0.985	Jinzhou Port	0.984
Yunda Express	0.999	Zhongyuan Expressway	0.976	Wuhu Port	0.984
Jinzhou Port	0.999	Jinzhou Port	0.973	China Southern	0.980
Freetrade Science & Technology	0.988	Aucksun	0.938	ZTO Express	0.970
China Southern	0.982	Freetrade Science & Technology	0.911	Aucksun	0.934
Sinotrans	0.965	China Southern	0.897	Freetrade Science & Technology	0.867
COSCO Shipping	0.887	Nanjing Port	0.700	COSCO Shipping	0.836
Nanjing Port	0.871	Xinning Logistics	0.628	Nanjing Port	0.717
Xinning Logistics	0.791	Winbase	0.499	Yantian Port	0.680
Winbase	0.568	Yantian Port	0.429	Xinning Logistics	0.649
Yantian Port	0.271	ZTO Express	0.200	Winbase	0.499

4. Conclusions

By analyzing the data of 2017-2019, it's found that there is still room for improvement in the input-output efficiency of listed Chinese logistics companies. The status quo of development shows that the overall input-output efficiency of listed logistics companies are descending slightly. In particular, with regard to the improvement of PTE and scale efficiency, PTE has been changing in an unstable way and cannot meet the development needs of the whole industry. By category, the express delivery industry stands out from the four industries by dint of its top-ranking OTE, PTE and scale efficiency, with three-year technical efficiency approximating the ideal value of 1. Still, its scale efficiency is not that prominent among the four industries, and there is still much room for improvement. In addition, port operation companies and road transport companies have experienced

continuous decline in PTE for three consecutive years, leading to a widening gap from the ideal value.

In order to improve the output efficiency, logistics companies must on the one hand place more emphasis on the improvement of PTE by attaching importance to the technological research and development, promoting the application of new logistics technologies and persistently pursuing IT-driven development, such as introducing new technologies and new concepts (smart logistics, smart supply chain, block chain, IoT, etc.) into the operations of the company in order to boost the input-output efficiency. On the other hand, listed logistics companies should improve their core competitiveness, give play to their edge in business and the social resources available, and achieve society-wide integration of their own warehousing and transportation resources to boost business incomes. Moreover, Chinese logistics companies should beef up their logistics functions and expand operations into value-added services such as circulation processing, logistics information services, inventory management, logistics cost control, logistics plan design, and full-course logistics services, thereby broadening service coverage and improving profitability and scale efficiency.

Acknowledgment

The research is supported by the Minjiang University Principal Fund Project in 2021.

References

[1] Xue-ping Deng, Xu Wang. An empirical analysis of productive efficiency of Chinese logistics companies. Journal of Chongqing University (social science edition), 2009, (15): 43-47.

[2] Guo Cao, Lu Liu, Kefu Ying. An empirical analysis of the production efficiency of listed logistics enterprises. Statistics and Decision, 2016, (16): 184-188.

[3] Xiaonan Ma. Study on performance evaluation of listed logistics enterprise. Logistics Technology, 2013, (32): 239-241.

[4] Yao Qin, Wuyong Qian. Research on business performance of logistics enterprises based on dynamic multi-attribute grey target decision-making model, Logistics Sci-tech, 2019, (42): 8-15.

[5] Dayu Cheng, Shuo Wang. Study on AHP-logistics performance evaluation of listed, Logistics Sci-tech, 2014, (37): 117-121.

[6] Ruirui Zhang, Lina Jin, Shuang Wang. Evaluation of financial ability of listed logistics companies based on principal component analysis, Logistics Technology, 2017, (36): 68-72.

[7] Zhen Huang. The measurement of the input-output efficiency of logistics listed companies based on the mixed DEA model, Journal of Hunan Industry Polytechnic, 2019, (19): 31-35.