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THE APPLICATION OF DATA ENVELOPMENT ANALYSIS ON THE EFFICIENCY OF LOGISTICS ENTERPRISES

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Abstract. *With the development of logistics industry and the influence of globalization, more and more multinational logistics enterprises and strategic investors flock to Chinese logistics market. It is an urgent problem to evaluate the efficiency of Chinese logistics enterprises by an effective algorithm. In this paper, data envelopment analysis method is proposed to fulfill comprehensive efficiency for technical efficiency and scale efficiency of logistics enterprises. The validity and the significance are tested according to input-output indicators. Based on the empirical results, we adjust the input-output indicator values of logistics enterprises to attain the optimal efficiency.*
Keywords: Data envelopment analysis, Logistics enterprises, Technical efficiency, Scale efficiency

1. **Introduction.** Efficiency evaluation of logistics enterprise is a scientific comparative analysis between quantitative and qualitative method, which is to empirically analyze technical efficiency and scale efficiency for the logistics industry by establishing a suitable indicator system and adopting advanced method, further, to predict the future development prospect of management control behaviors.

Since early sixty of the last century, many scholars in European and American had researched logistics enterprise efficiency. In recent years, some scholars in our country have done beneficial explorations to evaluate comprehensive efficiency level of logistics enterprise by numerous foreign theorists and practitioners in the field. However, there still exists a significant gap compared with the advanced research methods [1,2]. Liu utilized panel data of Britain's 28 port enterprises in 1983-1990, taking business income as output indicator, and wages payment as human resource input indicator, gross fixed capital net value as capital input indicator, and established stochastic frontier production function model to evaluate comprehensive efficiency of port enterprises [3]. Shi et al. empirically analyzed comprehensive efficiency of 22 Chinese listed logistics company by data envelopment analysis model, the results of which help logistics enterprises to concern about competitiveness environment objectively and logistics efficiency levels [4]. Li and Li evaluated comprehensive efficiency of 52 listed logistics corporations in 2008 by one-stage data envelopment analysis method from the perspective of production efficiency and scale efficiency in order to explore the reasons of technical efficiency of logistics enterprises [5]. Wang and Zhong analyzed 25 listed logistics enterprises based on the panel data from 2004 to 2011. The results indicated that there did not exist significant relationships between scale efficiency and comprehensive efficiency of logistics enterprises,

controlling the enterprise operation risk and reducing enterprise assets and liabilities can help logistics enterprises to improve efficiency level [6]. Yao and Zhuang empirically analyzed comprehensive efficiency of Chinese logistics industry based on panel data from 30 Chinese provinces and cities from 2000 to 2008. The results showed that human capital and fixed assets investment could prompt from efficiency of Chinese logistics, logistics industry [7]. There are many techniques about logistics efficiency evaluation, which include quantitative approaches and qualitative approaches. The quantitative approaches consist of single-objective method and multi-objective method, and the frequently-used methods include analysis hierarchy progress (AHP) method, fuzzy comprehensive evaluation (FCE) method, principal component analysis (PCA) method, data envelopment analysis (DEA) method and so on. Qualitative research is a method of inquiry employed in many different academic disciplines, including in the social sciences and natural sciences, but also in non-academic contexts including market research, business, and service demonstrations by non-profits [8]. In order to synthetically consider the principles of objectivity and practicality in the research of logistics enterprise's efficiency evaluation methods, DEA method is used in this paper, in order to improve logistics market's efficiency. DEA method overcomes subjectivity of qualitative approaches compared with AHP method and FCE method, which is based on a set of observations about input and output to estimate efficient production frontier. Moreover, it can utilize linear programming to judge the decision marking unit's corresponding to point depending on the efficient production frontier, and can acquire much useful management information as well [9-11].

2. **Data Envelopment Analysis (DEA) Method.** Data envelopment analysis is a method to evaluate the efficiency of decision units based on principle of linear programming, which calculates the production frontier of all decision units, and then adapts to the relative position of all decision making units and production frontier surface to judge their efficiency. It is efficient in locating the production frontier for decision making units; otherwise, it is inefficient. The method does not need to estimate the functional relationships between the input and output variables [12-14]. When the listed logistics enterprises are in the production process, we construct data envelopment analysis model to evaluate comprehensive efficiency of logistics enterprises as follows.

$$\max \rho_r^* = \frac{u^T Y_r}{v^T X_r} = \frac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}}$$
$$\text{s.t.} \begin{cases} \dfrac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, & (j = 1, 2, \ldots, n) \\ u_k \ge 0, & (k = 1, 2, \ldots, s) \\ v_i \ge 0, & (i = 1, 2, \ldots, m) \end{cases} \tag{1}$$

In Formula (1), ρ_r^* is the comprehensive efficiency level for listed logistics enterprise, x_{ij} is the input indicator, y_{kj} is the output indicator, and v_i and u_k are weight. If $\rho_r^* = 1$, the efficiency of listed logistics enterprise is the most efficient; when $\rho_r^* < 1$, the efficiency of listed logistics enterprise is less efficient. If θ_r^* is the technology efficiency level, π_r is the scale efficiency level. The correlation rule is defined as follows:

$$\rho_r^* = \theta_r^* * \pi_r^* \tag{2}$$

If the efficiency value of a listed logistics enterprise is less efficient, the slack values have been existing in input indicators or output indicators. The main problem is that some sections are parallel to the axis (Figure 1) due to the piecewise linear frontier. In Figure

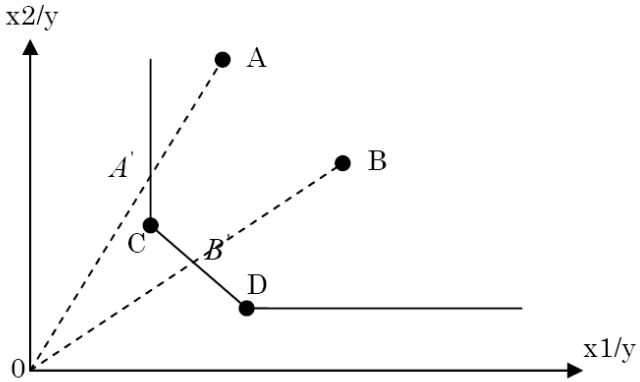

FIGURE 1. Slack analysis principle

1, C and D are used to represent two efficient listed logistics enterprises, and A and B represent two inefficient listed logistics enterprises. If we reduce the input value x_2, the same output is constant, and this situation is called input-slack (s^-). If we consider more input-output conditions, there may exist input-slack (s^-) or output-slack (s^+).

3. **Indicators Selection and Data Sources.** In this paper, there are two input indicators including total assets and operating costs, and output indicators including net profit, operating income and earning per share. Earning per share refers to the ratio of after tax profits to equity. It is an important indicator to reflect the profitability of listed logistics enterprises. The indicators are seen in Table 1.

TABLE 1. Input-output indicators of listed logistics enterprises

Input Indicators		Output Indicators		
Total Assets (million yuan)	Operating Costs (million yuan)	Operating Income (million yuan)	Net Profit (million yuan)	Earnings per Share
I_1	I_2	O_1	O_2	O_3

See Table 2, the raw data come from the Annual Report of Chinese Listed Companies from 2006 to 2015.

4. **Results Analysis on Efficiency Values of Logistics Enterprises.** According to the linear programming model (1), by using the software deap2.1, we can calculate the raw indicators data to gain different efficiency values from 2006-2015 including the comprehensive efficiency value, the pure technical efficiency, the scale efficiency value, the radial-slack movement tendency. By observing the efficiency values tendency, it is clear that most of logistics enterprise keep different changes in different times. Firstly, during 2006-2008, the comprehensive efficiency value, the pure technical efficiency and the scale efficiency of logistics enterprise have reached 1.0 such as Shanghai port, Yantian port and Xiamen airport, but the pure technical efficiency level and scale efficiency value of northern Bay Port and Chongqing port logistics enterprise are lower. Secondly, during 2009-2012, the comprehensive efficiency value, pure technical efficiency and scale efficiency of logistics enterprise have reached 1.0, the samples are Beibu Gulf port, Yantian port and Xiamen airport, especially the development of Beibu Gulf port is rapid, which may have certain positive connections with enterprise innovation reform. Lianyun port is the lowest in the efficiency value of and scale efficiency which is less than 0.5. The other logistics enterprises such as Nanjing port, Yingkou port and Chongqing port are lower in most of pure technical efficiency value. Thirdly, during 2013-2015, the comprehensive efficiency values, the pure technical efficiency and the scale efficiency of logistics enterprises have

TABLE 2. Raw data of listed logistics enterprises

	Input indicators		Output indicators		
	I_1	I_2	O_1	O_2	O_3
Jinzhou port	862648	72404	114885	16444	0.1
Dalian port	2233316	281874	397056	66578	0.2
Beibu port	353705	109107	145138	16714	−0.39
Lianyun port	395017	86433	119692	10631	0.27
Nanjing port	87111	8522	14983	2299	0.13
Rizhao port,	1069588	225322	311463	47361	0.4
Shanghai port	7457931	1261501	2123327	575425	0.14
Lingang group	140942	78180	98433	1191	0.03
Tianjin port	2275617	936085	1185741	116836	0.36
Xiamen port	357664	286467	318685	20425	0.32
Yantian port	533876	17489	41417	54005	0.57
Xiamen airport	357664	41350	88202	31331	0.42
Yingkou port	1114830	164710	248793	34401	0.64
Chongqing port	438748	77741	105066	7831	0.15
Tielong logistics	427047	239496	298462	35464	0.3
Guangshen railway	3010460	953266	1234013	122260	0.17

TABLE 3. The efficiency level of logistics enterprises

Logistics enterprises/Year/Efficiency	2006-2008			2009-2012			2013-2015		
	ρ_r^*	θ_r^*	π_r^*	ρ_r^*	θ_r^*	π_r^*	ρ_r^*	θ_r^*	π_r^*
Jinzhou port	0.95	1.00	0.95	0.83	0.93	0.89	0.64	0.65	0.98
Dalian port	0.83	0.87	0.95	0.71	0.72	0.99	0.71	0.76	0.93
Beibu port	0.49	0.73	0.67	1.00	1.00	1.00	0.96	1.00	0.96
Lianyun port	0.93	1.00	0.93	0.4	0.87	0.46	0.71	0.73	0.97
Nanjing port	0.84	1.00	0.84	0.72	0.75	0.96	0.70	0.74	0.95
Rizhao port	0.74	0.75	0.99	0.81	0.81	1.00	0.82	0.83	0.99
Shanghai port	0.92	1.00	0.92	0.87	0.95	0.92	0.87	0.93	0.94
Lingang group	1.00	1.00	1.00	0.92	1.00	0.92	0.95	0.96	0.99
Tianjin port	0.90	1.00	0.90	0.85	0.85	1.00	0.94	0.98	0.96
Xiamen port	0.92	0.88	1.05	0.84	0.84	1.00	1.00	1.00	1.00
Yantian port	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Xiamen airport	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yingkou port	0.98	1.00	0.98	0.71	0.72	0.99	0.74	0.78	0.95
Chongqing port	0.66	0.85	0.78	0.67	0.70	0.96	0.77	0.77	1.00
Tielong logistics	0.92	1.00	0.92	1.00	1.00	1.00	0.95	0.97	0.98
Guangshen railway	0.68	0.82	0.83	0.83	0.85	0.98	0.90	0.92	0.98

reached 1.0, the samples are Xiamen port, Yantian port and Xiamen airport, the scale efficiency value of some logistics enterprises as Jinzhou port, Dalian port, Lianyungang, Nanjing port, Yingkou port and the port of Chongqing fluctuate within the range between 0.6-0.8, most of pure technical efficiency value fluctuate over 0.7, but still they did not reach the most efficient level.

From Figure 2, we can find that only the comprehensive efficiency change tendency of Yantian port and Xiamen airport listed logistics enterprises is stable, the other listed logistics enterprises such as Tianjin port, Xiamen port, Tielong Logistics are not obvious for comprehensive efficiency values change tendency, the value fluctuations are within

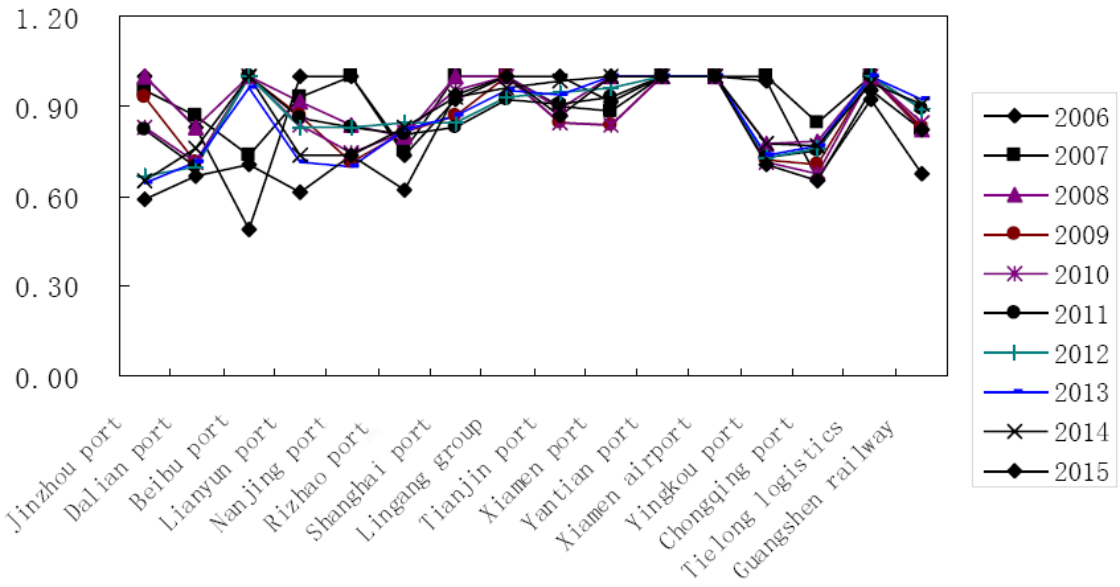

FIGURE 2. Change tendency of comprehensive efficiency values of logistics enterprises

0.9-1.0. In other words, the comprehensive efficiency values tendency of some logistics enterprises are obvious including the Jinzhou port, Dalian port, Lianyun port, Nanjing port, Rizhao port, Yingkou port, Chongqing port. From the results we can infer that most of logistics enterprises development periodically changes which will be an important study problem to take effective measures to promote enterprise efficiency.

5. **Conclusions and Future Work.** The data envelopment analysis approach in the paper solves mainly two major problems. Firstly, it improves the correctness of algorithm of comprehensive efficiency for pure technical efficiency and scale efficiency of logistics enterprise. Secondly, it improves most non-significant efficiency of logistics enterprise. Furthermore, one main feature of data envelopment analysis method proposed that it can be used to deal with multi-input and multi-output models, and can calculate the efficiency value effectively without the distribution assumption. Moreover, it tolerates that the inefficiencies exist which can be deduced easily. In addition, the cost efficiency is helpful to analyze the comprehensive efficiency, and employing operations are all the same with the classic envelopment analysis approach. We think that it is feasible to increase the environmental variables in the linear equation by constructing three-stages DEA methods, further to analyze cost efficiency value tendency of logistics enterprise in future work.

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