Cost Performance Analysis of Cold Chain Logistics Based on DEA Model

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Abstract. The development of the cold chain logistics industry affects the solution of China's "three rural" problems to a certain extent. Evaluating and improving the business performance of cold chain logistics enterprises is not only conducive to reducing the circulation links of agricultural products, reducing the circulation cost of agricultural products, but also effectively guaranteeing the quality of agricultural products. This paper innovatively proposes a cold chain logistics cost performance analysis model based on the DEA-AHP model. The model can dynamically evaluate the development trend of the company's cold chain logistics level through the comparison of consecutive years in the cold chain logistics company. This is beneficial to the company's profit expectations and forecasting of development prospects. The research results show that the technical level is the key factor affecting the efficiency of enterprise operation, followed by the management style and the scale of enterprise operation. Finally, according to the experimental results, this paper puts forward some suggestions for the development of cold chain logistics enterprises.

Keywords: DEA model · cold chain logistics · cost performance · enterprise efficiency

1 Introduction

At the beginning of 2015, the central government proposed to "innovate the circulation mode of agricultural products", and some recent policies have shown the orientation of "cold chain logistics is king, and those who control the supply chain of agricultural products will win". From the current point of view, the main body of China's agricultural product circulation is mainly cold chain logistics enterprises. Its high-efficiency operation and healthy development play an important role in improving the agricultural product industry chain, improving the quality of life of farmers, improving the current situation of China's rural areas, and promoting agriculture to the market effect. There are many forms of cold chain logistics enterprises, and they play different roles in different links of cold chain logistics. The healthy and good operation of cold chain logistics enterprises can effectively promote the technology research and development, equipment renewal and resource integration of the entire agricultural cold chain industry and marketization [3].

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The development of China's cold chain logistics industry is relatively late. Cold chain logistics enterprises have many problems in the operation process, such as high cost, insufficient hardware facilities, low technical content and low efficiency. Therefore, accurate evaluation of their enterprise performance is important for judging cold chain. The development status and existing problems of logistics enterprises are of great significance. Therefore, based on the data collection of cold chain logistics enterprises, this paper will conduct a comprehensive evaluation of the performance of cold chain logistics enterprises based on the AHP-DEA model according to the characteristics of cold chain logistics enterprises.

2 DEA Model Establishment, Analysis and Evaluation

2.1 C^2R Model and C^2GS^2 Model

DEA method is very suitable for the evaluation of the efficiency of cold chain logistics enterprises [5]. This paper attempts to build a performance evaluation index system based on financial indicators, using DEA method C^2R model and C^2GS^2 model, the former can be used to evaluate the overall effectiveness of decision-making units, while the latter can be used to evaluate the pure technical effectiveness of decision-making units. This paper analyzes and evaluates the performance of 16 listed cold chain logistics enterprises in China from 2008 to 2010, compares the performance differences between port and transportation enterprises, and puts forward countermeasures and suggestions.

Model C^2R assumes that there are N decision-making units (this article is a listed cold chain logistics company), and each decision-making unit DMU_j has m types of inputs and s types of outputs. Suppose the weight vectors of input and output are respectively: $v = (v_{1,} v_{2,} \ldots v_{i,})^T$, $u = (u_{1,} u_{2,} \ldots u_{r,})^T$ then the efficiency of DMU_j can be expressed as:

$$h_j = \frac{u^T Y_j}{v^T X_j} \tag{1}$$

The j_0 DMU relative efficiency $C^2R - DEA$ evaluation model is:

$$\text{Max} \;\; h_0 = \frac{u^T Y_0}{v^T X_0}$$

$$\text{s.t}\; u^T Y_j - v^T X_j \le 0 \;\; j = 1, 2, 3, \ldots n$$

$$u \ge 0, v \ge 0 \tag{2}$$

Convert Eq. (2) into a linear programming:

$$\text{Max} \;\; u^T Y_0$$

$$\text{s.t} \;\; v^T X_j - u^T Y_j \ge 0, \;\; j = 1, 2, 3, \ldots n \tag{3}$$

The dual problem of this linear programming is:

$$\sum_{j=1}^{n} \lambda_j Y_j - Y_0 \leq 0$$

$$\lambda_j \geq 0, \quad j = 1, 2, 3, \ldots n \tag{4}$$

Add s_{i0}^{+}, s_{r0}^{-} which is a slack variable, and ε is a non-Archimedes number (ε is set to 10^{-7}), then model one is obtained.

Model one:

$$\begin{aligned}
&\text{Min } \{\rho_0 - \varepsilon(\sum_{i=0}^{n} s_{i0}^{+} + \sum_{r=1}^{s} s_{r0}^{-})\} \\
&\text{s.t} \sum_{j=1}^{n} \lambda_j x_{ij} + s_{i0}^{+} = \rho_0 x_{i0} \quad i = 1, 2, 3, \ldots m \\
&\sum \lambda_j y_{rj} - s_{r0}^{-} = y_{r0} \quad r = 1, 2, 3, \ldots s \\
&\lambda_j \geq 0 \quad j = 1, 2, 3, \ldots n
\end{aligned}$$

$$\rho_0, s_{i0}^{+}, s_{r0}^{-} \geq 0 \tag{5}$$

This paper adds the constraints of $\sum_{j=i}^{n} \lambda_j = 1$ to obtain the D model.

Model two:

$$\begin{aligned}
&\text{Min } \{\theta_0 - \varepsilon(\sum_{i=1}^{n} s_{i0}^{+} + \sum_{r=1}^{s} s_{r0}^{-})\} \\
&\text{s.t} \sum_{j=1}^{n} \lambda_j x_{ij} + s_{i0}^{+} = \theta_0 x_{i0} \quad i = 1, 2, 3, \ldots m \\
&\sum \lambda_j y_{rj} - s_{r0}^{-} = y_{r0} \quad r = 1, 2, 3, \ldots s \\
&\sum_{j=1}^{n} \lambda_j = 1 \quad j = 1, 2, 3, \ldots n \\
&\lambda_j \geq 0
\end{aligned}$$

$$\theta_0, s_{i0}^{+}, s_{r0}^{-} \geq 0 \tag{6}$$

In this paper, the DEA model can be solved by [x, f] = linprog (f, [], [], Aeq, beq, lb, ub) (Fig. 1).

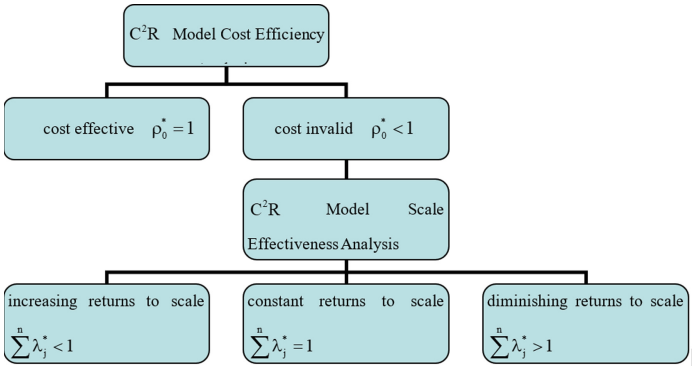

Fig. 1. C^2R Model analysis and evaluation ideas

2.2 Analysis and Evaluation of the Model

2.2.1 Overall Effectiveness Analysis

If there is λ_j^*, so that $\sum_j^n \lambda_j^* = 1$, then DEA is the constant return to scale; if $\sum_j^n \lambda_j^* > 1$, then DEA is the diminishing return to scale; If $\sum_j^n \lambda_j^* < 1$, then DEA is increasing returns to scale.

2.2.2 Analysis of Pure Technical Efficiency and Pure Scale Efficiency

Let θ_0^*, λ^*, s_{i0}^+, s_{r0}^- be the optimal solution of model 2, there are the following conclusions: 1) if $\theta^* = 1$, then the decision-making unit is DEA pure technology is valid; 2) if $\theta^* < 1$, then the decision-making unit is DEA pure technology is invalid; 3) if $\theta^* = 1$, and $s^{+*} = 0$, $s^{-*} = 0$, then the decision-making unit is purely technically effective with weak DEA.

3 Empirical Analysis

3.1 Decision-Making Unit and Indicator System

3.1.1 Selection of Decision-Making Unit and Indicator System

Decision-making unit refers to a cold chain logistics listed company that invests a certain number of production factors and has a certain amount of output. This paper selects a total of 16 cold chain logistics enterprises listed in Shenzhen and Shanghai as samples, and the name of each cold chain logistics enterprise is subject to the stock exchange [1]. When using DEA to analyze the overall efficiency and scale efficiency of a company, it is not appropriate to use the specific raw materials and output value of finished products of each company as input-output indicators, because each company has different raw materials and finished products due to different business scopes. The dominant principle of data envelopment analysis is that each DMU has the same input and output in a certain

Table 1. Input indicators of 16 listed cold chain logistics companies

Company Name	Total assets (ten thousand yuan)			Main cost (ten thousand yuan)		
	18	19	20	18	19	20
Sifang Technology	712466	752822	1011969	457989	526170	545590
Songzhi shares	5002859	5592954	4071017	1111077	726041	895084
Hanbell Precision Machinery	5908129	6554699	6589466	896299	916464	996825
China Reserve Shares	1454678	1466109	1625547	147817	156528	190557
Aucma	515572	552787	620218	81591	67106	75505
Suning Online Market	1984965	2144085	2251146	817575	695260	825525
SF Holding	259516	245590	505555	65895	68962	86868
Ice Wheel Environment	55942	92106	50065	6021	7871	6951
CIMC Group	795521	842751	947668	1511779	1514145	1740186
Guanghong Holdings	5455786	5755858	5415064	4144686	1697462	4506576
agricultural products	264970	506988	550116	99499	97791	144125
Bright Dairy	15575	40171	41055	6972	9946	15192
Wanhua Chemical	6242455	8299759	10014621	1109954	1158219	2292155
Juhua Shares	2892719	2955741	5060449	816006	859942	917876
Haier Smart Home	465415	557575	614206	516064	199110	509562
Intel Group	54606	48506	105000	2956	15570	64455

perspective. We define a company as a homogeneous organization that makes use of its assets to make profits through operations, and evaluate its relative rate. The selected input indicators are mainly indicators related to enterprise assets, including total assets (I_1) and main business costs (I_2), and the specific data are shown in Table 1; output indicators are mainly indicators related to enterprise profitability, including main business income. (O_1), net profit (O_2) and earnings per share (O_3), see Table 2 for specific data. These five indicators can basically reflect the operating performance of China's cold chain logistics listed companies, and the data of each indicator are taken from the annual reports of each company from 2018 to 2020.

In terms of input: total assets refer to all assets owned or controlled by an economic entity that can bring economic benefits, reflecting the overall strength of the company; the cost of main business is directly related to the output benefits of the company.

In terms of output: the ultimate goal of the company's production and operation is profit. Net profit is the most frequent indicator to measure the company's benefits which can reflect the company's profitability [7]. The size of the capacity; earnings per share reflect the company's ability to expand its equity.

Table 2. Output indicators of 16 listed cold chain logistics companies

Company Name	Main business income (ten thousand yuan)			Net profit (ten thousand yuan)			Earnings per share (yuan)		
	18	19	20	18	19	20	18	19	20
Sifang Technology	663371	369015	315979	133822	13550	33995	1.11	0.10	0.26
Songzhi shares	1753563	891335	1139893	537300	106379	171652	1.58	0.31	0.5
Hanbell Precision Machinery	1770389	1617033	1865515	361933	376003	531712	0.22	0.18	0.26
China Reserve Shares	318333	183372	257293	123312	33312	61580	0.36	0.10	0.18
Aucma	185571	131858	168923	63289	31886	59668	1.00	0.65	0.93
Suning Online Market	1073535	923252	1076686	93181	63326	80327	0.57	0.38	0.38
SF Holding	98103	98583	121389	10177	7339	11052	0.19	0.13	0.21
Ice Wheel Environment	10905	12152	8323	931	573	1331	0.03	0.02	0.06
CIMC Group	1607138	1399591	1833310	15355	18258	27772	0.21	0.25	0.33
Guanghong Holdings	3631728	1981939	5066332	130690	95896	300185	0.53	0.36	1.13
agricultural products	152261	156685	218553	29358	37138	37631	0.29	0.37	0.37
Bright Dairy	13151	18087	23606	2070	2635	1693	0.36	0.37	0.19
Wanhua Chemical	2193322	2273921	3082629	662817	713668	1031083	0.35	0.38	0.70
Juhua Shares	1082235	1151138	1258085	121182	135732	155589	0.17	0.19	0.22
Haier Smart Home	328018	218285	339188	62779	22907	33611	0.69	0.25	0.39
Intel Group	11222	23629	80029	3528	5335	7633	0.20	0.30	0.33

3.1.2 Selection of Sample Size

The question of sample size for evaluating firms is determined by the number of input and output variables [6]. The following relational formula connects the sample size of the evaluation enterprise as K and the number of input types to be considered as N and the number of output types as M. It is based on empirical findings and the experience of DEA practice: $K \geq 2(N + M)$. In this paper, 16 listed cold chain logistics companies are selected as samples, which meet the requirements of the number of samples.

3.2 Data Processing

According to the selected 2018–2020 input-output index data (Tables 1 and 2), bring the data into model 1 and model 2, use MATALB to optimize and solve, and calculate the total number of 16 listed cold chain logistics companies in 2018–2020. Efficiency

Table 3. Model 1 and Model 2 optimal solutions ρ_0^*, θ_0^*, S_0^*

Years	2018			2019			2020		
Company Name	ρ_0^*	θ_0^*	S_0^*	ρ_0^*	θ_0^*	S_0^*	ρ_0^*	θ_0^*	S_0^*
Sifang Technology	0.3536	0.5888	0.8818	0.6616	0.8325	0.8853	0.8828	0.8393	0.9098
Songzhi shares	0.5109	0.6028	0.8385	0.2688	0.3018	0.8883	0.2823	0.3803	0.8352
Hanbell Precision Machinery	0.9883	0.9989	0.9895	0.2823	0.3952	0.5803	0.2818	0.328	0.8283
China Reserve Shares	0.5233	0.5889	0.9055	0.3115	0.3583	0.8989	0.3825	0.6823	0.8028
Aucma	0.8102	0.8638	0.9299	0.3126	0.3216	0.9888	0.6038	0.6236	0.9681
Suning Online Market	0.8813	0.9389	0.9291	0.5331	0.8886	0.6193	0.3953	0.3188	0.9363
SF Holding	0.5629	0.6238	0.9025	0.3133	0.3883	0.8302	0.5363	0.6505	0.8398
Ice Wheel Environment	0.536	0.5823	0.953	1	1	1	1	1	1
CIMC Group	0.1881	0.3185	0.5609	0.336	0.5363	0.8128	0.3351	0.3932	0.8822
Guanghong Holdings	0.2386	0.3809	0.3962	0.3558	0.8828	0.303	0.3828	0.3103	0.9328
agricultural products	0.6081	0.6931	0.8859	0.3228	0.6633	0.3866	0.6628	0.698	0.9509
Bright Dairy	1	1	1	0.8562	0.9856	0.8688	1	1	1
Wanhua Chemical	0.9956	0.9982	0.9983	0.9016	0.9065	0.9936	1	1	1
Juhua Shares	0.9121	0.9229	0.9883	0.3233	0.3332	0.8338	0.3593	0.3615	0.9932
Haier Smart Home	0.3109	0.3225	0.9825	0.9852	1	0.9852	0.5858	0.6122	0.9305
Intel Group	1	1	1	0.8523	0.9523	0.8939	0.9885	1	0.9885

ρ^*, pure technical efficiency θ^* and pure scale efficiency S_0^*, the pure scale efficiency is calculated from $S^* = \rho^*/\theta^*$, the results are shown in Table 3.

4 Recommendations

Uneven allocation of technical resources and insufficient technical development. For example, the comprehensive efficiency and pure technical efficiency of Juhua Co., Ltd. are both low. The main reason is that the company's technical resources are unevenly distributed, which leads to deviations in the company's technological development, which affects the company's innovation and development and the efficiency of its development.

The unreasonable scale of production and operation and resource input lead to the failure of enterprise operation efficiency to reach the optimal state. Judging from the input-output status indicators, many enterprises have redundant input resources, which not only leads to low operating efficiency, but also wastes resource costs. At this time,

the amount of resource input should be reduced and adjusted to the best input and output [4]. When the input-output ratio is optimal, the scale of production should be expanded or reduced in the same proportion according to the current situation of increasing or decreasing returns to scale. In view of the above problems, the following suggestions for improvement are proposed:

Increase the focus on R&D and innovation of logistics technology. The technical level of an enterprise directly affects the pure technical efficiency of the enterprise, which greatly affects the utilization rate of the enterprise's resource investment. Therefore, technological development is the core driving force for improving the operational efficiency of cold chain logistics enterprises [2]. It should adhere to innovative development, introduce intelligent cold chain preservation equipment, electronic monitoring equipment, etc.; at the same time, establish an intelligent information sharing platform to monitor the real-time status of cold storage, refrigerated trucks and other equipment at any time, and improve the quality of fresh products in transit.

Reasonably allocate the proportion of resource input, and seek the appropriate production and operation scale of the enterprise. The redundancy of input resources increases the cost of enterprise operation and reduces the efficiency of enterprise operation. When the output rate is found to be low during the operation of the enterprise, do not rush to increase the investment of resources. You should start from various aspects to find the problem, and reasonably allocate the investment ratio of enterprise resources and services according to the technological development of the enterprise, so as to avoid resource redundancy but still the problem of low productivity.

Expand the recruitment of senior talents and scientific research personnel, and improve the scientific research management level of enterprises. The efficient operation of an enterprise is inseparable from high-level skills and technology, so it is necessary to strengthen the incentive and management of senior scientific research talents. High-level talents are the source of enterprise innovation, and the introduction of talents can provide a huge driving force for the improvement of enterprise innovation efficiency. At the same time, we should also pay attention to the training and improvement of the company's existing talent capabilities, and establish and improve talent management mechanisms and talent incentive policies.

5 Conclusions

The overall efficiency of Chinese cold chain logistics listed companies is not high, and there are significant differences in efficiency; from the analysis of pure technical effectiveness, the pure technical efficiency of Chinese cold chain logistics listed companies is relatively stable, but their combination of input elements is not reasonable, no achieve better output. From the analysis of scale efficiency, the scale efficiency of Chinese listed cold chain logistics enterprises is relatively good. It can be seen that the main reason for the low overall efficiency of listed cold chain logistics enterprises in China is the poor pure technical efficiency rather than the scale efficiency.

References

1. Ge C, Lin S (2020) Research on cost accounting and control methods of fresh cold chain logistics enterprises in Shaanxi Province under the background of new retail. Fortune Today (China Intellect Prop) 8:81–82
2. Hu X, Lu P (2020) Cost analysis and control of flower cold chain logistics. Logist Eng Manag 42:46–54
3. Li M, Li D (2021) Analysis and control of cold chain logistics cost of agricultural products from the perspective of poverty alleviation and agricultural assistance. 5:151–153
4. Liu Z, Li J, Song L (2022) Cost analysis of cold chain logistics based on blockchain and RFID technology. J Wuhan Univ Technol Inf Manag Eng 44:90–94
5. Su C, Zhang Y (2022) The cost investigation and control strategy of green food cold chain logistics in Yunnan. Agric Technol 42:40–50
6. Tang L (2021) Research on the performance evaluation of dairy cold chain logistics in the internet of things environment. Mod Commer Ind 42:23–32
7. Wang X, Wu M (2020) Research on the loss and cost control of Gansu agricultural products in cold chain logistics. Logist Eng Manag 42:39–44