Research on Efficiency Evaluation of Logistics Industry in Liaoning Province Based on Three-stage DEA-Malmquist Model Under Low-carbon Constraints

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Abstract. Green and low-carbon development has become the main theme of China's current development, starting from the perspective of low carbon, the logistics efficiency index system of Liaoning Province is constructed, and the three-stage DEA model and Malmquist model are used to analyze the low-carbon logistics efficiency of 31 provinces and cities in China from 2014 to 2021 from the dynamic and static dimensions. The results show that the efficiency of the logistics industry in Liaoning Province is slightly higher than the national average at this stage, and the pure technical efficiency is closely related to the overall efficiency, and the low-carbon logistics efficiency still needs to be continuously improved.

Keywords: three-stage DEA model, Malmquist model, Low-carbon logistics efficiency.

1 INTRODUCTION

Nowadays, the country attaches more and more importance to green development, and low-carbon logistics has become the only way to build an ecological civilization country. In this context, it is of great significance to study the efficiency of the logistics industry in Liaoning Province from a low-carbon perspective and put forward targeted countermeasures, which is of great significance for Liaoning to realize the low-carbon construction of the industry.

With the rapid progress of the logistics industry, domestic scholars have become more and more extensive in their research on logistics efficiency. Hui Qing et al. analyzed the efficiency of cold chain logistics through the DEA-Malmquist model to explore the relationship between various elements.[1].Zhang Yunfeng et al. found that there are external factors that affect the efficiency of the logistics industry through the SFA model [2]. At the same time, the logistics efficiency under low-carbon constraints has also received the attention of many scholars.Shu Liangyou and Zhai Xiaoya compared the efficiency of the logistics in Henan Province with that of the whole country by establishing a logistics index system under low-carbon constraints, and found that logistics technology and management level play a constraining role in efficiency [3].

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2 STUDY DESIGN

2.1 Model Selection

Three-stage DEA can separate the influence of environmental variables on the efficiency accuracy from the static dimension, and combine it with the Malmquist model to measure its change trend through the dynamic dimension.

Three-stage DEA model: The first-stage BCC model was used to calculate the preliminary DEA efficiency value of Liaoning Province by using DEAP2.1 software. In the second stage of the SFA model, the relaxation variables and environmental indicators were substituted into the Frontier 4.1 software for SFA analysis, and the input indicators were adjusted. In the third stage of the BCC model, the adjusted input variables are substituted into the BCC model for recalculation, and the adjusted efficiency value of the logistics industry is calculated. Malmquist model: The adjusted input index data and raw output data of the second stage were selected, and the Malmquist model was run by DEAP2.1 software to investigate the productivity changes in different periods from the dynamic dimension.

2.2 Indicator Selection

In accordance with the principles of importance, availability, scientificity and comparability, combined with the current situation of logistics development in Liaoning Province, and the relevant research results, the analysis indicators of low-carbon logistics efficiency are established from multiple perspectives. According to the traditional production model, the input indicators are selected from the perspectives of three production factors: human input, material input and financial input, considering the low-carbon constraints, carbon dioxide emissions are added to the input index system, and output indicators are selected from the perspectives of production capacity and transportation capacity [4].

For the selection of environmental indicators, we consider four aspects: economic environment, consumption level, scientific and technological development and government guidance, as shown in Table 1 below:

Table 1. Analysis indicators of low-carbon logistics efficiency

Indicator type	The name of the metric	Indicator description
Input metrics	The number of employees in the logistics industry	Manpower input
	Mileage of transport routes in the logistics industry	Material input
	Investment in fixed assets in the logistics industry	Financial investment
	CO_2 emissions	Contamination situation

Output indicators	Gross domestic production of the logistics industry Freight volume Cargo turnover	production capacity Shipping capacity Shipping capacity
Environmental indicators	Gross Domestic Product R&D funding Per capita consumption expenditure of residents Fiscal expenditure of the logistics industry	level of economic development level of science and technology Regional consumption levels Government support

2.3 Data Source

This paper mainly studies the overall situation of the efficiency of low-carbon logistics industry in Liaoning Province from 2014 to 2021, so selects 31 provinces as DMUs, based on the fact that China does not divide the concept of logistics industry into the industrial system, after sorting out the relevant literature, it is found that the added value of industrial data of transportation, warehousing and postal industry accounts for most of the logistics industry, so the sum of its data is selected to represent the relevant data of the logistics industry. The data of each indicator are from the China Statistical Yearbook and Liaoning Statistical Yearbook.

In consideration of low-carbon constraints, according to the China Energy Statistical Yearbook, we understand 8 main forms of energy consumption [5], and use the main energy consumption to estimate carbon dioxide emissions, and the calculation refers to the IPCC method, and the calculation formula is as follows:

$$TC = \sum_{i=1}^{n} E_i \times CF_i \times CC_i \times COF_i \times (44/12) \tag{1}$$

E_i indicates the ith energy consumption of each province; CF_i indicates the calorific value of energy combustion; CC_i indicates the carbon content; COF_i denotes oxidation factor; $CF_i \times CC_i \times COF_i \times (44/12)$ indicates the co_2 emission factor.

3 EMPIRICAL ANALYSIS

3.1 The Results of the Traditional DEA Model Were Analyzed in the First Stage

The DEA-BCC model in DEAP2.1 software was used to analyze the data related to national logistics efficiency and the relaxation variables of input variables from 2014 to 2021, as shown in Table 2.

Table 2. The efficiency value of logistics industry in Liaoning Province from 2014 to 2021

Year	Comprehensive technical efficiency	Pure technical efficiency	Economies of scale	Remuneration for scale
2014	0.826	0.826	1.000	-
2015	0.653	0.657	0.998	drs
2016	0.687	0.826	0.833	drs
2017	0.642	0.698	0.921	drs
2018	0.625	0.663	0.945	drs
2019	0.867	0.882	0.964	irs
2020	1.000	1.000	1.000	-
2021	1.000	1.000	1.000	-
Mean	0.788	0.819	0.958	-

From 2014 to 2019, the comprehensive technical efficiency fluctuated and was less than 1, indicating that the allocation of resources was unreasonable and needed to be optimized. In 2020 and 2021, the scale efficiency values of the three are all 1, indicating that the utilization of logistics input resources is reasonable and the relative efficiency is high in these two years, the pure technical efficiency value of the remaining years is about 0.6-0.8, indicating that the production efficiency affected by technology has not been maximized, and the scale efficiency that can remove the influence of technical factors is 1 in 2014, 2020 and 2021, indicating that the investment can achieve the highest benefit at the lowest cost .

Through horizontal and vertical two-dimensional comparative analysis, longitudinal comparison of the three efficiency averages shows that the comprehensive technical efficiency is closer to the frontier of efficiency than the scale efficiency, and the technical efficiency has not been effective in 5 out of 8 years, and the scale efficiency value has been greater than the comprehensive technical efficiency value, indicating that there is a lot of room for development in technology production; from the horizontal point of view, the national average efficiency values are: 0.706, 0.798, 0.883, and the three efficiency averages in Liaoning Province are higher than the national level, but there is still a big gap with the high-efficiency areas.

3.2 The Regression Results of the SFA Model Were Analyzed in the Second Stage

The relaxation variable of the input index measured by the first stage of DEA model was taken as the dependent variable, and the environmental index was taken as the independent variable, and the SFA regression analysis was carried out by using Frontier 4.1 software [6], and the analysis results under the influence of environmental factors are shown in Table 3.

Table 3. SFA model regression results

Variable	Relaxation variables for logistics practitioners	Relaxation variable in the amount of investment in fixed assets	Transport route mileage relaxation variables	CO_2 emissions relaxation variables
Constant terms	-692.654***	-8.673***	-2347.369***	-38.236***
GDP	-7.536***	-0.057***	0.093	-0.020
CPI	-0.398	0.003	-0.036	0.001
R&D funding	187.345***	0.472	-5.324***	0.264
Fiscal expenditure of the logistics industry	328.457***	1.389***	-0.834	0.385
sigma-squared	971843.403***	36.71***	221749.083***	2382.453***
gamma	0.938***	0.834***	0.995***	0.923***
LR	12.453	11.352	13.596	17.485

Note: *** indicates significant at the 1% level

It can be seen from Table 3 that the regression coefficient of the relaxation variable between GDP and logistics industry employees and fixed asset investment is negative and significant at the level of 1%, indicating that the economy can promote employment and improve the regional low-carbon logistics efficiency to a certain extent; the per capita consumption expenditure of residents has no significant relationship with the relaxation variables of the other four input indicators, indicating that the per capita consumption expenditure has little impact on the input index of low-carbon logistics efficiency in Liaoning Province; the regression coefficient of R&D expenditure and the relaxation variable of logistics employees is positive, and R& The increase in expenditure will exacerbate the redundancy of personnel, and have a certain degree of positive impact on the investment index of the mileage of transportation routes. The regression coefficient of the fiscal expenditure of the logistics industry and the relaxation variables of logistics employees and fixed asset investment is positive and significant, indicating that if the government provides too much support, it will lead to the waste of employees and assets, and hinder the improvement of regional logistics efficiency. In general, the input index will be affected by environmental factors, which will affect the accuracy of efficiency measurement, so the third stage of adjustment of the input index should be carried out through the DEA model.

3.3 Analysis of the Results of the Adjusted DEA Model in the Third Stage

The efficiency values of 31 provinces and cities in China were measured again in the DEAP2.1 software, and the results of the first and third phases were compared, as shown in Table 4.

Table 4. The adjusted efficiency of the logistics industry in Liaoning Province

Year	Comprehensive technical efficiency	Pure technical efficiency	Economies of scale	Remuneration for scale
2014	0.943	0.926	0.982	irs
2015	0.834	0.917	0.996	irs
2016	0.851	0.989	0.948	irs
2017	0.876	0.843	0.935	-
2018	0.787	0.891	0.942	irs
2019	0.906	0.948	1.000	irs
2020	1.000	1.000	1.000	-
2021	1.000	1.000	1.000	-
Mean	0.899	0.939	0.973	-

After adjustment, the efficiency values have been improved to a certain extent, indicating that environmental factors have a negative impact on the efficiency of low-carbon logistics in Liaoning Province. The overall scale efficiency is increasing and approaching a stable stage, and the development scale is gradually rationalized, but it has not yet reached the best state, and there is still a lot of room for improvement. Liaoning Province is located in the northeast of China, and due to its strategic geographical location, the logistics industry has great potential for development and is currently in a booming stage. However, the relative lag of logistics technology restricts the improvement of logistics efficiency in Liaoning Province, and advanced logistics technology should be actively introduced and applied at this stage to improve the operational efficiency of the logistics industry. From a macro point of view, there is still a certain gap between Liaoning Province and the regions with higher domestic logistics efficiency. When formulating the development strategy of the logistics industry, the actual local situation should be fully considered, and the overall improvement of logistics efficiency should be realized through precise positioning and innovative development model.

3.4 Analysis of the Results of the Malmquist Model

For further study the dynamic trend and the reasons for the change of low-carbon logistics efficiency in Liaoning Province and obtain more comprehensive evaluation results, the Malmquist model in DEAP2.1 software was used to analyze the dynamic trend, and the analysis results are shown in Table 5.

Table 5. Malmquist efficiency value of Liaoning Province from 2014 to 2021

Time period	effch	techch	pech	sech	tfpch
2014-2015	1.072	0.946	1.058	1.016	1.015
2015-2016	0.984	2.005	1.002	0.981	1.937
2016-2017	0.906	0.673	0.968	0.941	0.616
2017-2018	1.084	1.582	1.037	1.049	1.714
2018-2019	0.997	0.864	0.953	1.042	0.793
2019-2020	1.004	1.012	1.000	1.008	1.027
2020-2021	1.023	1.005	1.008	1.021	1.022
Mean	1.010	1.155	1.003	1.008	1.161

From 2014 to 2021, the total factor productivity fluctuated up and down, and the value was above 1 for most of the period. On the whole, the index of change of technological progress is the closest to the index of total factor productivity, indicating that the level of productivity is mainly affected by the index of change of technological progress. The change index of pure technical efficiency is greater than that of scale efficiency change index in 2014-2017, and the change index of scale efficiency exceeds that of 2018-2021, indicating that it has been improved in the allocation process and the economies of scale are more obvious. Through the analysis of the results, it is found that technology plays a vital role in the progress of logistics efficiency in Liaoning Province, and advanced logistics technology should be vigorously developed and configured to drive the progress of the logistics industry in the whole region.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

From a low-carbon perspective, this paper uses DEA and Malmquist models to measure the low-carbon logistics efficiency in Liaoning Province from 2014 to 2021.

The efficiency of low-carbon logistics in Liaoning Province is indeed affected by environmental factors, and the effectiveness of each factor has changed after the environmental factors are removed. The improvement of the level of regional economic development can promote the rational use of labor, capital and other resources, and promote the efficiency of low-carbon logistics, but if the government support is too large, it will cause a waste of manpower, capital and other resources, which affects the efficiency of low-carbon logistics.

The overall efficiency of the logistics industry in Liaoning Province is higher than the national average, but there is still a long way to go from those areas with greater room for development. At present, the logistics industry in Liaoning Province is facing outstanding problems such as low resource utilization rate and high carbon emissions. On the whole, the comprehensive efficiency of logistics in Liaoning Province is fluctuating, in which the pure technical efficiency is lower than the scale efficiency, indicating that the improvement of industrial efficiency depends on the continuous development of technology.

4.2 Recommendations

Based on the above conclusions, the following suggestions are put forward for Liaoning Province as a whole:

Rationally allocate resources to reduce carbon emissions. Rationally plan resource inputs, reduce waste, and prioritize clean energy. Hire experts and technicians to assess the logistics process and ensure that resources are used efficiently. Strengthen the recycling of logistics waste, improve the reuse rate of resources, and promote the progress of low-carbon logistics industry.

Pay attention to talent training and innovation-driven development. The government should increase investment in scientific research, improve the talent training system, and enterprises should organize training to improve the ability of employees. At the same time, we will build a collaborative platform for logistics information, use smart logistics to promote industrial upgrading, and widely apply advanced technologies such as 5G technology and artificial intelligence to the logistics industry to achieve high-quality progress of the logistics industry.

Promote the linkage development of regional industries and realize the complementary advantages of industries. We will build a comprehensive economic pilot zone with Liaoning characteristics, explore a new model of opening up and development, give full play to the positive role of the external environment in promoting the logistics industry, and promote the sustainable and healthy development of the logistics industry in Liaoning Province.

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