Research on Evaluation of Port Logistics Efficiency Based on DEA-Malmquist Model

Xiaoning Zhang
School of Economics and Management, Beijing Jiaotong University, Beijing, China
19120596@bjtu.edu.cn

Abstract. Port logistics, as an important carrier supporting the trade exchanges of countries around the world, has a positive driving effect on economic growth. This paper adopts the DEA-Malmquist index evaluation model and takes the panel data of my country's top ten coastal port logistics from 2012 to 2019 as the research object for empirical research. By constructing a reasonable evaluation index system, using DEA method to conduct static analysis of port logistics efficiency, and using Malmquist index method to conduct dynamic analysis of port logistics efficiency. Finally, according to the results of the logistics efficiency evaluation, targeted countermeasures and suggestions are put forward to provide reference for the improvement of my country's port logistics efficiency.

1. Introduction
With the development of economic globalization and trade globalization, the volume of trade between countries has increased significantly. Port logistics, as an important carrier supporting the trade exchanges of countries around the world, has a pivotal position in import and export trade, and provides basic support for the country's economic construction development. Therefore, studying the efficiency of port logistics and its influencing factors has extremely important value for improving the development of port logistics and world trade.

In recent years, scholars have achieved certain results in the study of port logistics efficiency evaluation. Xi Lei etc. used the data envelopment analysis method to perform DEA analysis on the four index data of Shanghai Port from 2009 to 2015, and the results showed that the logistics efficiency of Shanghai Port was at a relatively ideal level [1]. Deng Juan applied the DEA model to evaluate and evaluate the efficiency of China's ports above designated size [2]. Jiang Jianhong etc. constructed a PCA-DEA two-stage method to evaluate the logistics efficiency of port enterprises, and the results showed that the overall logistics efficiency of port enterprises was low [3]. Jia Yulian used the network DEA model to conduct a two-stage study on the logistics of Ningbo Zhoushan Port [4]. Liu Zhong etc. considered the randomness of port data and the uncertainty of the weights of various indicators, and used the stochastic DEA model to evaluate the efficiency of the logistics of four coastal ports in Zhejiang Province [5].

In summary, in the research on port logistics efficiency, scholars mainly use DEA method for static analysis, but there are few related studies on dynamic analysis of port logistics efficiency using Malmquist index. Therefore, this paper uses the DEA-Malmquist model to study port logistics efficiency.
2. Research methods and theoretical basis

2.1. Data Envelopment Analysis (DEA)

Assuming that there are a total of n decision-making units, in each decision-making unit there are m types of inputs and s types of outputs, the dual program corresponding to the linear programming of the CCR model is:

\[
\begin{align*}
\min & \quad \theta \\
\text{s.t.} & \quad \sum_{j=1}^{n} \lambda_j x_j + S^- = \theta x_0 \\
& \quad \sum_{j=1}^{n} \lambda_j y_j - S^+ = y_0 \\
& \quad S^- \geq 0, S^+ \geq 0, \lambda_j \geq 0
\end{align*}
\]

(1)

Among them, \( \lambda_j \) is the weight vector of the input-output vector. The value of \( \theta \) can reflect the input and output efficiency of the decision-making unit. If \( \theta^* = 1 \), the decision-making unit is valid for DEA under the CCR model. On this basis, the constraint condition \( \sum_{j=1}^{n} \lambda_j = 1 \) can be added to form variable returns to scale conditions, and BCC models can be generated, which can be used to evaluate technical efficiency under different returns to scale.

2.2. Malmquist index model

The Malmquist index model is constructed as follows:

\[
M(x_t, y_t, x_{t+1}, y_{t+1}) = \left( \frac{D^e_t(x_{t+1}, y_{t+1})}{D^e_t(x_t, y_t)} \right) \times \left( \frac{D^e_t(x_{t+1}, y_{t+1})}{D^e_t(x_t, y_t)} \right)^{-\frac{1}{2}}
\]

(2)

When \( M > 1 \), total factor productivity shows an increasing trend from period \( t \) to period \( t+1 \); when \( M = 1 \), it shows a stagnant state; when \( M < 1 \), it shows a downward trend.

3. Evaluation index selection and data sources

3.1. Evaluation index selection

On the basis of referring to the existing research results, taking into account the applicability principle of the evaluation index selection and the principle of data availability, this paper selects two input indicators of terminal length and number of berths, and two output indicators of port annual cargo throughput and port annual container throughput.

3.2. Data Sources

This paper selects the annual panel data of the input-output index values of my country's Shanghai Port, Ningbo Zhoushan Port, Shenzhen Port, Guangzhou Port, Qingdao Port, Tianjin Port, Yantai Port, Rizhao Port, Yingkou Port and Dalian Port from 2012 to 2019. The data mainly comes from the "China Statistical Yearbook", "China Port Yearbook" and provincial statistical yearbooks.

4. Empirical analysis

Use DEAP2.1 software to calculate the input-output indicators of my country's top ten coastal port logistics from 2012 to 2019.
4.1. Static analysis of port logistics efficiency

4.1.1. Comprehensive technical efficiency analysis

The comprehensive technical efficiency of the top ten coastal ports from 2012 to 2019 is shown in Table 1. It can be seen from Table 1 that in terms of the top ten coastal ports selected in this article, the overall technical efficiency of logistics fluctuates from 2012 to 2019. There was a downward trend in 2012-2014, an upward trend in 2014-2017, and a downward trend in 2017-2019. From the perspective of various ports, the comprehensive technical efficiency value of the three coastal ports of Shenzhen Port, Qingdao Port and Rizhao Port has remained at 1 in the past 8 years, indicating that the logistics input and output of these three ports have reached DEA effectively and the logistics efficiency is high; Yingkou Port The average value of the port’s overall efficiency in the past 8 years is above 0.8, and the logistics efficiency is also at a relatively high level; The average value of the overall technical efficiency of the other six ports in the past eight years is below 0.8, indicating that the logistics efficiency of these six ports is relatively low and needs to be improved.

| Port              | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | average |
|-------------------|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| Shanghai          | 0.383    | 0.415    | 0.368    | 0.392    | 0.475    | 0.549    | 0.543    | 0.541    | 0.458   |
| Ningbo Zhoushan   | 0.482    | 0.471    | 0.468    | 0.488    | 0.512    | 0.596    | 0.570    | 0.564    | 0.519   |
| Shenzhen          | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Guangzhou         | 0.474    | 0.538    | 0.456    | 0.507    | 0.511    | 0.612    | 0.612    | 0.587    | 0.537   |
| Qingdao           | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Tianjin           | 0.726    | 0.689    | 0.687    | 0.681    | 0.701    | 0.761    | 0.697    | 0.637    | 0.697   |
| Yantai            | 0.536    | 0.503    | 0.513    | 0.556    | 0.573    | 0.446    | 0.562    | 0.500    | 0.524   |
| Rizhao            | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Yingkou           | 0.883    | 0.854    | 0.788    | 0.808    | 0.840    | 0.995    | 0.896    | 0.605    | 0.834   |
| Dalian            | 0.466    | 0.470    | 0.449    | 0.448    | 0.476    | 0.557    | 0.513    | 0.409    | 0.474   |
| average           | 0.695    | 0.694    | 0.673    | 0.688    | 0.709    | 0.752    | 0.739    | 0.684    |         |

4.1.2. Pure technical efficiency analysis

The pure technical efficiency of the top ten coastal ports from 2012 to 2019 is shown in Table 2. It can be seen from Table 2 that in terms of the top ten coastal ports selected in this paper, the average pure technical efficiency of logistics has maintained above 0.8 from 2012 to 2019, indicating that it has maintained a high degree of technicality. From the perspective of each port, the pure technical efficiency value of the five coastal ports of Shanghai Port, Ningbo Zhoushan Port, Shenzhen Port, Qingdao Port and Rizhao Port has remained at 1 in the past 8 years, indicating that the logistics input resources of these five ports have been fully utilized; The average value of pure technical efficiency of Yingkou Port and Tianjin Port in the past 8 years has maintained above 0.8, maintaining a relatively high technical efficiency; The average value of the pure technical efficiency values of the other three ports in the past 8 years is lower than 0.8, indicating that the technical effectiveness is insufficient.

| Port              | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | average |
|-------------------|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| Shanghai          | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Ningbo Zhoushan   | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Shenzhen          | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Guangzhou         | 0.544    | 0.694    | 0.490    | 0.542    | 0.566    | 0.744    | 0.749    | 0.691    | 0.628   |
| Qingdao           | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000   |
| Tianjin           | 1.000    | 1.000    | 1.000    | 1.000    | 0.972    | 0.776    | 0.705    | 0.687    | 0.893   |

Table2. 2012-2019 my country's top ten coastal port logistics pure technical efficiency value
4.1.3. Scale efficiency analysis

The scale efficiency of the top ten coastal ports from 2012 to 2019 is shown in Table 3. It can be seen from Table 3 that in terms of the ten major coastal ports selected in this article, the overall trend is increasing. From the perspective of each port, the scale efficiency value of the three ports of Shenzhen Port, Qingdao Port and Rizhao Port has been maintained at 1 in the past 8 years, indicating that the logistics input resources of these three ports have been effectively used and their logistics allocation capabilities are relatively high; Dalian Port The scale efficiency values of the four ports, Yingkou Port, Guangzhou Port, and Tianjin Port in the past 8 years were 0.953, 0.896, 0.864, and 0.800, respectively, maintaining high scale efficiency; while Yantai Port, Ningbo Zhoushan Port and Shanghai Port The average scale efficiency of each port in the past 8 years is below 0.8, indicating that the scale efficiency is insufficient.

Table3. 2012-2019 my country's top ten coastal ports logistics scale efficiency value

| Port      | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | average |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|---------|
| Shanghai  | 0.383 | 0.415 | 0.368 | 0.392 | 0.475 | 0.549 | 0.543 | 0.541 | 0.458   |
| Ningbo Zhoushan | 0.482 | 0.471 | 0.468 | 0.488 | 0.512 | 0.596 | 0.570 | 0.564 | 0.519   |
| Shenzhen  | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Guangzhou | 0.872 | 0.776 | 0.931 | 0.935 | 0.904 | 0.823 | 0.817 | 0.850 | 0.864   |
| Qingdao   | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Tianjin   | 0.726 | 0.689 | 0.687 | 0.681 | 0.722 | 0.981 | 0.989 | 0.927 | 0.800   |
| Yantai    | 0.729 | 0.729 | 0.723 | 0.757 | 0.765 | 0.799 | 0.983 | 0.863 | 0.794   |
| Rizhao    | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Yingkou   | 0.969 | 0.919 | 0.913 | 0.933 | 0.935 | 0.995 | 0.896 | 0.605 | 0.896   |
| Dalian    | 0.964 | 0.966 | 0.974 | 0.978 | 0.968 | 0.971 | 0.990 | 0.813 | 0.953   |
| average   | 0.813 | 0.797 | 0.806 | 0.816 | 0.828 | 0.871 | 0.879 | 0.816 |         |

4.2. Dynamic analysis of port logistics efficiency

This paper analyzes the structural changes of the Malmquist index from the perspective of technical efficiency and technological progress, and analyzes the dynamic changes of the logistics efficiency of my country's top ten coastal ports (Table 4).

Table4. 2012-2019 my country's top ten coastal port logistics Malmquist index changes and decomposition

| Port      | effch  | techch | Malmquist Index |
|-----------|--------|--------|-----------------|
| Shanghai  | 1.051  | 1.006  | 1.057           |
| Ningbo Zhoushan | 1.023 | 1.005 | 1.028           |
| Shenzhen  | 1.000  | 1.014  | 1.014           |
| Guangzhou | 1.031  | 1.006  | 1.037           |
| Qingdao   | 1.000  | 1.003  | 1.003           |
| Tianjin   | 0.981  | 1.006  | 0.987           |
| Yantai    | 0.990  | 1.002  | 0.992           |
| Rizhao    | 1.000  | 1.006  | 1.006           |
| Yingkou   | 0.948  | 1.005  | 0.952           |
| Dalian    | 0.982  | 1.003  | 0.985           |
| average   | 1.000  | 1.006  | 1.006           |
According to the Malmquist Index of my country’s top ten coastal ports in Table 4, Shanghai Port, Ningbo Zhoushan Port, Shenzhen Port, Guangzhou Port, Qingdao Port and Rizhao Port increased by 5.7%, 2.8%, 1.4%, 3.7%, and 0.3% respectively. And 0.6%, of which Shanghai Port, Ningbo Zhoushan Port and Guangzhou Port are due to the improvement of both technical efficiency and technological progress, Shenzhen Port, Qingdao Port and Rizhao Port are mainly due to the improvement of technological progress; the Malmquist index of other ports are different The degree of reduction.

As shown in Table 5, the average annual technical efficiency of my country's port logistics from 2012 to 2019 is 1, the annual average value of technological progress in the same period is 1.006, and the annual Malmquist index is 1.006. This shows that the overall Malmquist index of my country's port logistics during the study period was 1. The upward trend is mainly due to the improvement of technological progress.

| Years     | effch | techch | Malmquist Index |
|-----------|-------|--------|-----------------|
| 2012-2013 | 1.004 | 1.035  | 1.039           |
| 2013-2014 | 0.961 | 1.099  | 1.056           |
| 2014-2015 | 1.031 | 0.955  | 0.985           |
| 2015-2016 | 1.042 | 0.969  | 1.010           |
| 2016-2017 | 1.066 | 0.896  | 0.955           |
| 2017-2018 | 0.990 | 1.091  | 1.079           |
| 2018-2019 | 0.916 | 1.011  | 0.926           |
| average   | 1.000 | 1.006  | 1.006           |

5. Conclusion and suggestion
This paper uses DEA and Malmquist index to analyze the logistics efficiency of my country's top ten coastal ports from 2012 to 2019. The results show that:

1) The logistics efficiency of the three coastal ports of Shenzhen Port, Qingdao Port and Rizhao Port has achieved DEA effectiveness; the three coastal ports of Shanghai Port, Ningbo Zhoushan Port and Yingkou Port need to adjust their logistics scale and rationally allocate logistics input resources; Dalian Port needs to focus on improving technical level: The three coastal ports of Guangzhou Port, Tianjin Port and Yantai Port need to further optimize the scale of logistics production while focusing on improving the level of logistics technology and management.

2) Empirical studies have shown that technological progress has played a significant role in the growth of logistics efficiency. The application, development and promotion of modern information technologies such as artificial intelligence, big data, and cloud computing in logistics have promoted the intelligent construction of all aspects of logistics. Therefore, the development of my country's port logistics should pay attention to the development and application of logistics technology to improve technical efficiency.

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