Research on Logistics Efficiency of Cities in Shandong Province Based on DEA-Malmquist Index Model

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Abstract. Based on the general background of logistics development, this paper establishes a logistics efficiency evaluation index system, and analyzes the logistics efficiency of the input-output panel data of 16 cities in Shandong Province from 2018 to 2021 based on DEA-Malmquist model. Research shows that from 2018 to 2021, except for Jinan, Qingdao, and Linyi, the comprehensive logistics efficiency of other cities did not reach DEA effectiveness; Through dynamic analysis, it can be seen that the overall logistics efficiency in Shandong Province is on the rise, but the utilization rate of investment resources and the scale of the logistics industry are still slightly insufficient.

Keywords: Logistics efficiency; Malmquist index model; Shandong Province

1.Introduction

As a fundamental, strategic, and leading industry supporting the development of the national economy, modern logistics plays an important supporting role in expanding effective investment and improving the quality of life of residents[1]. In recent years, Shandong Province, as an important junction of the Maritime and Land Silk Road, has experienced rapid development in its logistics industry, with its industrial scale constantly expanding[2]. According to statistics from the Development and Reform Commission of Shandong Province, the total amount of social logistics in Shandong Province in 2021 was 27.8 trillion yuan, an increase of 18.3% year-on-year; The total revenue of the logistics industry has reached 809.06 billion yuan, a year-on-year increase of 16.4% [3]. The total demand for logistics in society is constantly increasing, and the logistics industry structure is also constantly optimizing.

Shandong, as a coastal open province with superior natural environment and abundant natural resources, has obvious geographical advantages in developing logistics industry. It is located in the lower reaches of the Yellow River, facing the sea on both sides, and has a unique advantage in export-oriented logistics economy; The transportation is very convenient, with railways, highways, aviation in all directions[4]. However, the logistics industry in Shandong Province is currently in the stage of transformation and upgrading. Some cities have low logistics efficiency. Therefore, focusing on improving the quality and efficiency of urban logistics services is the

top priority for the transformation and upgrading of the logistics industry in Shandong Province[5].

By calculating and evaluating the logistics efficiency of 16 cities in Shandong Province, the differences in logistics efficiency among the 16 cities in the province are analyzed, which is of great significance for promoting the balanced development, transformation and upgrading of the logistics industry in Shandong Province [6].

2.Research methods and indicator construction

2.1DEA-Malmquist model construction

Based on the BCC model in DEA-Malmquist index model, this paper analyzes the logistics efficiency of 16 cities in Shandong Province, as shown in Model (1).

$$\min \theta$$

$$s.t. \begin{cases} \sum_{j=1}^{n} x_{ij}\lambda_{j} + s^{-} = \theta x_{i} \\ \sum_{j=1}^{n} y_{rj}\lambda_{j} - s^{+} = y_{r} \\ \sum_{j=1}^{n} \lambda_{j} = 1 \\ \lambda_{j}, \ s^{-}, \ s^{+} \geq 0, \ j = 1,2,...,n \end{cases} \tag{1}$$

Where, x_{ij} is the ith input of city j, $x_{ij} \geq 0$; y_{ij} is the rth output of city j, $y_{rj} \geq 0$; θ is the target planning value; λ_{j} is the programming decision variable; s^{+} and s^{-} are relaxation variable vectors. If $\theta = 1$, $s^{-} = 0$, $s^{+} = 0$, then the decision unit is DEA effective; If $\theta < 1$, then the decision unit is DEA invalid; If $\theta = 1$, and $s^{-} \neq 0$, $s+ \neq 0$, then the decision unit is weakly DEA efficient[7].

Malmquist index method can probe into the change of logistics efficiency of cities in Shandong Province, and its expression is in Models (2-5)[8]:

$$M(x^{t+1}, y^{t+1}, \ x^{t}, y^{t}) = \left[\frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t}, y^{t})} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})} \right]^{\frac{1}{2}} \tag{2}$$

$$Eech = \frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})} \tag{3}$$

$$Tech = \left[\frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})} \right]^{\frac{1}{2}} \tag{4}$$

$$Tfpch = Effch \times Tech = (Pech \times Sech) \times Tech \tag{5}$$

Where (x^{t}, y^{t}) and (x^{t+1}, y^{t+1}) are the input-output vectors of periods t and $t+1$ [9]. When $M > 1$, logistics efficiency is improved; When $M < 1$, it means that logistics efficiency decreases.

2.2 Index selection and data sources

Based on the principles of systematicity, typicality, and quantifiability in selecting evaluation indicators, logistics industry employees, transportation expenses, and road mileage are selected as input indicators, and freight volume, freight turnover, and total logistics business volume are output indicators. The specific indicators are shown in Table 1, with 16 cities in Shandong Province from 2018 to 2021 as the research object. The basic data mainly comes from the "Shandong Statistical Yearbook (2018-2021)" and statis-tical data from each city.

Table 1. Logistics efficiency evaluation index system of Shandong cities

Index classification	Indicator content	Units	Indicator code
Input indicator	Number of people employed in the logistics industry	Ten thousand people	X1
	Transportation expenditures	Ten thousand yuan	X2
	Highway mileage	Kilometers	X3
Output indicator	Freight volume	Tons	Y1
	Turnover of goods	Million tonne-kilometres	Y2
	Total logistics business	Hundreds of millions	Y3

3. Analysis of logistics efficiency of cities in Shandong Province based on DEA-Malmquist index

3.1 Static analysis of DEA model

Using DEAP, analyze and collate the collected data of cities in Shandong Province from 2018 to 2021, and calculate the comprehensive technical efficiency.

Table 2. Comprehensive efficiency values and rankings

Cities	2018	2019	2020	2021	Mean	Ranking
Jinan City	1.000	1.000	1.000	1.000	1.000	1
Qingdao	1.000	1.000	1.000	1.000	1.000	1
Zibo City	0.987	1.000	1.000	1.000	0.997	3
Zaozhuang City	0.676	0.590	0.696	1.000	0.741	8
Dongying City	0.678	0.469	0.491	0.507	0.536	11
Yantai City	0.742	0.743	0.732	0.735	0.738	9
Weifang City	1.000	0.983	0.880	0.844	0.927	4
Jining City	1.000	1.000	0.995	1.000	0.999	2
Tai 'an City	0.478	0.541	0.525	0.359	0.476	12
Weihai City	0.977	0.947	1.000	0.663	0.897	5
Rizhao City	0.657	0.702	0.666	0.701	0.682	10
Linyi City	1.000	1.000	1.000	1.000	1.000	1
Dezhou City	0.979	0.869	0.866	0.675	0.847	6

Liaocheng City	0.997	1.000	1.000	1.000	0.999	2
Binzhou City	0.891	0.884	0.648	0.697	0.780	7
Heze City	0.657	0.776	0.745	0.548	0.682	10
Mean	0.857	0.844	0.828	0.796	0.831	

As can be seen from **Table 2**, the average logistics comprehensive efficiency of 16 cities in Shandong Province is 0.831, and the overall logistics comprehensive efficiency shows a small downward trend. The highest efficiency value is 0.857 in 2018, and the lowest is 0.796 in 2021. Secondly, from the perspective of cities, the comprehensive efficiency of logistics in Jinan, Qingdao and Linyi is 1, indicating that the input-output of logistics industry has reached DEA efficiency. In addition to the above three cities and Liaocheng, Jining, Weifang, Weihai and Dezhou, the average logistics efficiency of other cities is lower than 0.831, and Tai' an ranks the last with an average value of 0.476, which is seriously low comprehensive efficiency.

3.2 Dynamic analysis of Malmquist index

It is very difficult to analyze the change of logistics efficiency from the static point of view, but the Malmquist index model can well analyze the change of logistics efficiency from the dynamic point of view [10]. Therefore, the Malmquist index model is used to make a dynamic analysis of the logistics industry data of 16 cities in Shandong Province during 2018-2021. The results are as follows.

Table 3. Changes and decomposition of Malmquist index in each year

Year	Effch	Techch	Pech	Sech	Tfpch
2018-2019	0.981	1.133	1.045	0.939	1.112
2019-2020	0.981	1.044	0.973	1.009	1.025
2020-2021	0.948	1.142	0.978	0.969	1.082
Mean	0.970	1.106	0.998	0.972	1.072

As shown in Table 3, from an average level, the mean Malmquist index of logistics industry in 16 cities of Shandong Province from 2018 to 2021 is 1.072, with an average annual growth of 7.2%, indicating that the logistics efficiency of all cities in Shandong Province is on the rise within the studied time interval. The effch obtained from the decomposition of tfpch is 0.970, with an average decrease of 3%, and the techch is 1.106, with an average increase of 10.6%, indicating that the growth of total factor productivity is mainly the result of the effect of technological progress. Further decomposition of the effch shows that the pech is 0.998, with an average decrease of 0.2%, and the scale efficiency sech is 0.972, with an average decrease of 2.8%, indicating that the decline of the technical efficiency is caused by the joint action of the pure technical efficiency and scale efficiency.

From the perspective of time, the increase of Malmquist index in 2018-2019, 2019-2020 and 2020-2021 is mainly the result of technological progress, which also reflects that technological progress has played an important role in promoting the sustainable and stable development of logistics industry.

Table 4. Variation and decomposition of Malmquist index in different cities

Cities	Effch	Techch	Pech	Sech	Tfpch
Jinan City	1.000	1.043	1.000	1.000	1.043
Qingdao City	1.000	1.118	1.000	1.000	1.118
Zibo City	1.004	1.006	1.000	1.004	1.011
Zaozhuang City	1.139	1.177	1.000	1.139	1.340
Dongying City	0.908	1.011	1.000	0.908	0.918
Yantai City	0.997	0.961	0.996	1.000	0.958
Weifang City	0.945	1.118	0.945	1.000	1.056
Jining City	1.000	1.009	1.000	1.000	1.009
Tai 'an City	0.909	1.378	1.079	0.842	1.253
Weihai City	0.879	1.037	1.000	0.879	0.911
Rizhao City	1.022	0.992	1.042	0.981	1.013
Linyi City	1.000	1.342	1.000	1.000	1.342
Dezhou City	0.884	1.247	0.982	0.900	1.102
Liaocheng City	1.001	1.092	1.000	1.001	1.093
Binzhou City	0.921	1.073	0.951	0.969	0.988
Heze City	0.942	1.188	0.978	0.963	1.118
Mean	0.970	1.106	0.998	0.972	1.072

From the perspective of cities, it can be seen from Table 4 that total factor productivity increases in 12 cities, among which 11 cities, Jinan, Qingdao, Zibo, Zaozhuang, Weifang, Jining, Tai 'an, Linyi, Dezhou, Liaocheng and Heze, the growth of Malmquist index is mainly due to the improvement of technological progress, while only Sunshine is due to the improvement of technological efficiency. The total factor productivity of four cities decreased, among which the Malmquist index of Dongying and Weihai decreased by 8.2% and 8.9% respectively, which was mainly due to the decline of scale efficiency. Yantai was mainly affected by the decline of technological progress, the Malmquist index decreased by 4.2%; While Binzhou was mainly affected by the decline of technical efficiency, which led to the decline of Malmquist index. It can be seen that technological progress is the main factor affecting the productivity of logistics industry. Cities in Shandong Province should attach importance to technological innovation and improve the application level of technology.

4.Conclusion

According to the DEA model, the average logistics efficiency of 16 cities in Shandong Province from 2018 to 2021 is 0.831, which is generally at a medium to high level, but there is still significant room for development. There are significant differences in logistics efficiency among different cities, with only Jinan, Qingdao, and Linyi achieving DEA effectiveness. According to the DEA-Malmquist index model, the overall logistics efficiency of cities in Shandong Province showed an upward trend from 2018 to 2021, with significant technological progress. However, the average pure technical efficiency and scale efficiency of each city were insufficient. Therefore, it is necessary to appropriately expand the scale of logistics operations in cities, improve the utilization rate of input resources, and promote the improvement of technical efficiency. Overall, there is a great imbalance in the logistics efficiency in various cities in

Shandong Province. It should strengthen the overall optimization of the logistics layout in each city, increase investment in infrastructure and resources, and improve their utilization rate.

References

[1] Chen, H.Y., & Chang, L.Y. (2023). Discussion on the high-quality development of modern logistics industry. Logistics Sci-Tech, (03): 64-65+68. DOI: 10.13714/j.cnki.1002-3100.2023.03.014.

[2] Wu, Y.H., (2019). Discussion on the development of logistics economy in Shandong Province in the context of the "the Belt and Road" strategy. Market Modernization, (03): 57-58. DOI: 10.14013/j.cnki.scxdh.2019.03.034.

[3] Wang, H. (2022) Analysis of the development of smart logistics in Shandong under the background of the internet economy. Money China, (21): 14-16. DOI: 10.19887/j.cnki.cn11-4098/f.2022.21.011.

[4] Wang, C.Y., Song, Y., Su, J., & Dong, S.S. (2023). Analysis on the development countermeasures of cold chain logistics industry of fruits and vegetables in Shandong Province. China Fruit & Vegetable, (02): 88-92. DOI: 10.19590/j.cnki.1008-1038.2023.02.015

[5] Xu, C.Y., Xu, H.J., &Qi, M. (2021). Comprehensive Evaluation of the Development Level of Urban Logistics in Shandong Province. Journal of Nanyang Institute of Technology, (04): 1-9. DOI: 10.16827/j.cnki.41-1404/z.2021.04.001.

[6] Zhang, J.K. (2019) Strategy analysis of logistics industry transformation and upgrading in Shandong Province. Market Modernization, (18):21-22. DOI: 10.14013/j.cnki.scxdh.2019.18.010.

[7] Wu, J.Q., Dong, Z.Q., Zhang, Y.Q., & Shi, X.G. (2022). Research on the efficiency evaluation and improvement measures of air logistics infrastructure supply in Yun-nan Province based on DEA Malmquist. China Market, (27):158-161. DOI: 10.1393939/j.cnki.zgsc.2022.27.158.

[8] Li, R., Luo, Y., Chen, B. et al. Efficiency of scientific and technological resource allocation in Chengdu–Chongqing–Mianyang Urban agglomeration: based on DEA–Malmquist index model. Environ Dev Sustain (2023). https://doi.org/10.1007/s10668-023-03153-9.

[9] Hui, Q., Pan, Z., & Chen, S. (2021). Evaluation of the efficiency of agricultural cold chain logistics in Hainan Province based on DEA. China Circulation Economy, (25): 15-18. DOI: 10.16834/j.cnki.issn1009-5292.2021.25.005.

[10] Wei, S.B., Shi, J.Y., Cheng, J. & Qiao, G.L. (2022). Evaluation of logistics industry efficiency in China Europe Railway Hub Cities based on DEA-Malmquist index model. China Storage & Transport, (09): 165-166. DOI: 10.16301/j.cnki.cn12-1204/f.2022.09.046.