

Research on Business Performance of Shandong Province Based on Three-Stage Data Envelopment Analysis

Ziyan Ren^{1,†}, Yushuo Wang^{2,†}, Ziyi Qiu^{3,†,*}

¹ School of Management, Qufu Normal University, Rizhao, China, 276800

² School of Rongcheng, Harbin University of Science and Technology, Weihai, China, 264300

³ School of Economics and Management, Northeast Agricultural University, Harbin, China, 150000

* Corresponding Author Email: qzydyx0305@163.com

† These authors contributed equally.

Abstract. Shandong Province ranks third in China in terms of economic output. The efficient operation of listed companies has contributed to the region's high economic growth to some extent. In order to improve the efficiency of enterprise operation, this paper takes 189 listed companies of various types in Shandong Province as the research object and constructs an efficiency evaluation index system through the three-stage data envelopment analysis to study the operational performance of enterprises from 2018 to 2022. Based on the research results, this paper puts forward suggestions for improving enterprise management. The research results show that only 2.12% of the sample enterprises have achieved the optimal efficient state in operation. The external environment has a significant constraint on the operation efficiency. Technical efficiency is the main factor affecting the operation efficiency of listed companies in Shandong Province, and enterprises have problems of waste and mismanagement in resource allocation and use. The operation efficiency of enterprises in different regions and industries is different. Based on the analysis results, this paper puts forward suggestions for the operation and management of listed enterprises in Shandong Province, improving their operational capabilities from both internal and external environment policies, promoting the balanced development of regional and industry economies.

Keywords: DEA, Business efficiency, Shandong Province.

1. Introduction

As a crucial economic pillar of China, Shandong Province boasts numerous listed companies that have significantly contributed to its economic growth. In 2023, there were 25 new listed companies in Shandong Province, and the province's GDP reached 9,206.87 billion yuan, marking a 6.0% increase from the previous year. The economic growth rate was also 0.8 percentage points higher than the national average. The per capita disposable income of the province's residents rose by 6.2% to reach 39,890 yuan compared to the previous year. During the "14th Five-Year Plan" period, Shandong Province continued to enhance support policies for listed companies and improve their quality and efficiency. This led to an increase in operating income by 8.9%, total profit by 12.1%, and net profit by 21.7% for provincial enterprises. However, compared with developed areas such as Beijing and Guangzhou, there are still gaps in resource allocation and management efficiency of listed companies in Shandong Province. Improving operating efficiency is essential for sustainable enterprise development; therefore, scientifically evaluating and analyzing the operating efficiency of listed companies is crucial for guiding them towards optimized management practices. Compared with existing evaluation methods, it has been found that first-stage DEA tends to overlook environmental variables' impact and random factors while second-stage DEA may result in large errors when measuring efficiency values. In this study, a three-stage data envelopment analysis model was established to determine input-output relationships along with environmental variables for listed companies in Shandong Province so as to measure their operating efficiency objectively.

2. Literature Review

Listed companies with high operating efficiency will promote the economic and industrial development of the region, and the use of scientific and efficient methods to calculate the operating efficiency of listed companies can optimize the management of enterprises, which has become the current research focus of different types of companies to optimize the management of enterprises. The existing research on the management efficiency of the company mainly includes the construction of the evaluation index system of the management efficiency and the application of scientific evaluation methods.

2.1. Evaluation methods of operating efficiency of listed companies

The existing methods to evaluate the operating efficiency of enterprises in China mainly include DEA, Malmquist index method, and the DEA analysis method mainly includes BCC and CCR evaluation models. For example, Peng Leiyi et al. [1] analyzed the operating efficiency of the hostel industry in Hangzhou in 2019 by establishing a three-stage DEA model, and used the super-efficiency model to analyze benchmarking enterprises, and concluded that the non-DEA effective hostel was caused by the combination of pure technical efficiency and scale efficiency. Wang Xinyi et al. [2] established a three-stage DEA model to analyze the operation efficiency of listed companies in Hefei, and put forward relevant management suggestions for the operation of listed companies in the region; Cui Mingfeng [3] analyzed the operational efficiency of Chinese commercial banks from 2015 to 2021 by establishing a three-stage DEA-Tobit model, drew a conclusion that the scale, innovation degree, profitability and development ability of Chinese commercial banks at the present stage had a positive impact on their operational efficiency, and put forward relevant suggestions for the development of commercial banks. Wu Zongze et al. [4] used the DEA-BCC model and the Malmquist index to conduct static analysis of the operational efficiency of 58 domestic listed logistics companies from 2015 to 2021, and analyzed the factors affecting the operational efficiency with the help of the DEA-Tobit model. It is concluded that the company's operating efficiency can be improved by reducing the investment in fixed assets and improving the utilization of capital. High fixed asset turnover and high profit rate have positive effects on operating efficiency under homogeneous environment. Yin Yue et al. [5] analyzed the operating efficiency of 24 property insurance companies by establishing DEA model, and concluded that human capital structure, business concentration and Internet insurance degree had a significant impact on the operating efficiency of property insurance companies. Based on the DEA-ToBIT model, relevant suggestions were put forward for the development of property insurance companies in China. Li Xin [6] established DEA BCC model to analyze the operating efficiency of listed tourism companies, and concluded that the profitability, solvency, operating capacity, enterprise scale and ownership concentration of enterprises have significant impacts on the operating efficiency of enterprises, and put forward relevant suggestions on how to improve the market competitiveness of tourism companies. Bi Xiaolei [7] analyzed the operating efficiency of 20 advertising companies in China from 2017 to 2021 by establishing DEA model and Malmquist index, and concluded that technological progress has a significant contribution to the improvement of total factor productivity, and company size and operating cost rate are negatively correlated to the operating efficiency of advertising companies. The per capita output value and supplier concentration are positively related to the operating efficiency of advertising companies, while the influence of ownership concentration and government support is not significant. Wang Yuting [8] analyzed the operating efficiency of 44 listed media companies by using BCC model and Malmquist index, and concluded that idle resources, low utilization of technology and redundancy of personnel were the reasons leading to low TFP, and technological progress was the key to improving TFP. Li Wei [9] established DEA model on the basis of principal component analysis, analyzed the operating efficiency of 33 listed publishing companies, and put forward suggestions on enterprise management, enterprise scale, technology investment, etc. Wang Huiyan et al. [10] established a three-stage DEA model, analyzed the operational efficiency of new energy wind power manufacturing enterprises, and compared and judged the effectiveness and

shortcomings of DEA by modifying environmental influencing factors, so as to provide improvement suggestions for improving the market competitiveness of new energy manufacturing enterprises and promote the development of the industry.

The DEA of the existing research methods in the first stage has not eliminated the impact of environmental factors, random interference and management inefficiency, so there will be large errors in the calculated results of operation efficiency, and the results are not comprehensive enough to reflect, with certain limitations. The three-stage DEA fully considers the impact of environmental factors, and the operating efficiency of listed companies is more objective, accurate and true when environmental factors are excluded. Therefore, this paper adopts three-stage DEA method to study and analyze the operating efficiency of listed companies in Shandong Province.

2.2. Construction of operating efficiency index system

At present, the enterprise operating efficiency index system mainly includes two parts: operating input and operating output, in which operating input mainly includes fixed assets, intangible assets, operating costs, number of employees, total assets, etc., while operating output mainly includes net profit, earnings per share, return on equity, main business income, operating interest rate, etc. Gong Mingyan [11] took total assets, operating costs and number of employees as input indicators, and return on assets, operating income and net profit as output indicators to analyze the operating efficiency of listed expressway enterprises in China; Li Zhongshi et al. [12] analyzed the operating efficiency of listed banks with total deposits, owner's equity, fixed assets and operating expenditure as input indicators and total loans, net profit and operating income as output indicators. Zhang Liangyong et al. [13] took the proportion of R&D personnel, the proportion of total R&D investment to operating income, and the cost of main business as input indicators, and took main business income and non-operating income as output indicators to study the operating efficiency of the transformation from traditional automobile enterprises to new energy automobile enterprises. Tian Xiaoli et al. [14] established an operational efficiency evaluation system for private banks with total assets and total liabilities as input indicators and net profit, deposit absorption and operating income as output indicators; Xu Huifang [15] established an operational efficiency evaluation system for automobile manufacturing enterprises with employee compensation, management expenses, net fixed assets, R&D investment and sales expenses as input indicators and operating income and net profit as output indicators.

3. Research methodology

The DEA model was proposed in 1994 by Fare R, Grosskopf et al. It is a non-parametric analytical method that can be applied to evaluate the efficiency of economic activities or organisations with multiple inputs and outputs indicators, and the model can respond to the changes in the efficiency of the decision-making unit over a period of time from a dynamic perspective. However, we also realise that comparing the existing research methods, the one-stage DEA does not exclude the influence of external factors such as environmental factors on the efficiency results, so the measured results have a large number of errors and limitations, while the three-stage DEA considers more comprehensively and is more objective and accurate in evaluating the operational efficiency of listed companies. To sum up, the three-stage DEA model is chosen for further research and analysis in the study of this paper.

In the first stage: we chose the traditional DEA model (i.e. BCC model) and used the professional software DEAP2.1 to substitute the input and output data of listed companies in Shandong Province into the traditional DEA model. Through this step, we measured the initial comprehensive efficiency, pure technical efficiency and scale efficiency of each decision-making unit (DMU) and obtained the input slack variables.

In the second stage: in order to eliminate the influence of external environmental factors and random errors on the efficiency measures, we adjusted the data from the first stage using the SFA

(Stochastic Frontier Analysis) model and performed regression analyses using the Frontier 4.1 software, where we obtained values of the input variables after removing the environmental variables and stochastic factors. This step ensured that all research subjects were under the same level of external environment and random luck, thus reflecting more accurately the true efficiency of each decision unit. The calculation formula is:

$$x_{ij}^A = x_{ij} + \left[\max_j \left[z_j, \hat{\beta}^i \right] - z_j \hat{\beta}^i \right] + \left[\max_j \left\{ \hat{v}_{ik} \right\} - \hat{v}_{ik} \right] \quad (1)$$

In equation (1): x_{ij}^A is the adjusted inputs; x_{ij} is the pre-adjusted inputs; and $\left[\max_j \left\{ z_j, \hat{\beta}^i \right\} - z_j \hat{\beta}^i \right]$ is the external environmental factors adjusted for all decision-making units using the worst-case environment as the criterion.

In the third stage: we substitute the values adjusted in the second stage and the original data into the traditional DEA model again, and by using DEAP2.1 software to measure the efficiency again, we get the results of the efficiency of decision-making units excluding the influence of environmental and random errors. These results provide us with a more accurate and comprehensive evaluation of the efficiency of listed companies, which helps us to deeply analyse the operational efficiency of listed companies in Shandong Province and their influencing factors.

4. Data sources and selection of indicators

4.1. Data sources

This study is based on 309 listed companies in Shandong Province from 2018 to 2022, and 189 companies (hereinafter referred to as the ‘sample companies’) are finally selected as the research object after data elimination, and some of the sample companies involve finance-related companies. Cross-sectional data such as fixed assets, number of employees, operating costs, revenue from main business, return on net assets, net profit, government subsidies, number of years of establishment, and GDP per capita of the city where the listed company is located from 2018 to 2022 are selected as the research data, and the main data are obtained from the work reports of the government of each prefecture-level city in Shandong Province, CSMAR, and Flush Finance.

4.2. Selection of indicators

4.2.1 Input/output variable selection

To evaluate the level of operating efficiency of listed companies, as shown in Table I the fixed assets, number of employees, operating costs of enterprises from 2018 to 2022 are selected as input indicators; meanwhile, the return on net assets, net profit, and main business income of enterprises from 2018 to 2022 are selected as output indicators. The data were analyzed by correlation analysis to conclude that there is a correlation between the input and output indicators in this paper and the data satisfy the assumptions of the DEA model.

Table 1. Description of Input-Output Indicators for Evaluating the Operating Efficiency of Listed Companies in Shandong Province

Variable Type	Specific Indicators
Input Variables	Fixed Assets
	Number of Employees
	Business Costs
Output Variables	Return on Net Assets
	Net Profit
	Revenue from Main Operations

4.2.2 Environment variable selection

Environmental variables as external factors affecting the operational efficiency of the assessed enterprise, and these factors can not be completely by the assessment unit can be fully controlled, but will have a significant impact on the results of the measurement, so the environmental variables factors should be carefully selected in the measurement process. Referring to the research on the operating efficiency of listed companies in other provinces and cities, the three environmental variables of government subsidies, the number of years of establishment of enterprises, and the per capita GDP of the city are selected for research as shown in Table 2 for the years 2018-2022. Figure 1 shows the calculated integrated efficiency values for each prefecture-level city in Shandong Province in the first stage.

Table 2. Selection of Environmental Variables for Business Efficiency of Listed Companies in Shandong Province

Variable type	Specific Indicators
Environment Variables	Government Subsidy
	Years of Business Establishment
	Municipal GDP per Capita

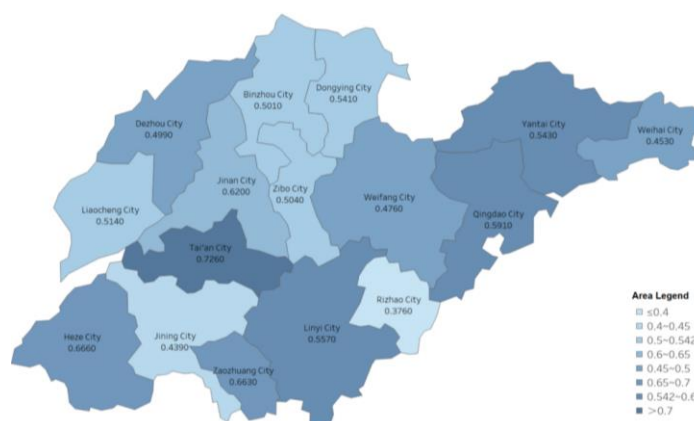


Figure 1. Comprehensive Efficiency Values of Prefecture-level Cities in Shandong Province in the First Stage

5. Analysis of Empirical Results

5.1. Stage 1: Analysis of the results of the traditional DEA model

The comprehensive efficiency, pure technical efficiency and scale efficiency of the sample enterprises in the first stage are shown in Table 3, which divides the capacity of the enterprises based on the comprehensive efficiency of DEA: the comprehensive efficiency equals to 1 on behalf of the strong capacity; at [0.8, 1) on behalf of the strong capacity; at [0.5, 0.8) on behalf of the general capacity; at [0.2, 0.5) on behalf of the weaker capacity; the efficiency is less than 0.2 on behalf of the weak capacity of the enterprises. weak capacity of the enterprise.

Table 3. Results of the first stage efficiency measurement of the sample firms

Efficiency Value interval	Combined efficiency		Pure technical efficiency		Scale efficiency	
	Number of enterprises	Percentage	Number of enterprises	Percentage	Number of enterprises	Percentage
<0.2	2	1.06%	2	1.06%	0	0
[0.2, 0.5)	83	43.92%	67	35.45%	0	0
[0.5, 0.8)	86	45.50%	91	48.15%	10	5.29%
[0.8, 1.0)	15	7.94%	21	11.11%	176	93.12%
1	3	1.59%	8	4.23%	3	1.59%

It can be seen that among the sample enterprises, there are only 3 enterprises with strong comprehensive efficiency capability, accounting for only 1.59% of the total number of sample enterprises; there are 15 enterprises with strong capability, accounting for 7.94% of the total number of enterprise samples; while there are 86 enterprises at the general level, accounting for 45.50% of the total number of enterprise samples; there are 85 enterprises below the general level, accounting for 44.98% of the total number of enterprise samples; 55.03% of the sample The capacity of 55.03% of the enterprises in the sample reaches the general level and above. 63.49% of the enterprises in the sample reach the general level and above in terms of pure technical efficiency, and although the distribution of pure technical efficiency is generally consistent with that of the comprehensive efficiency, the level of pure technical efficiency is slightly higher compared with that of the comprehensive efficiency. The overall level of scale efficiency is relatively high, and the distribution of efficiency values differs considerably from that of comprehensive efficiency and pure technical efficiency, with 100 per cent of the enterprises achieving general efficiency.

5.2. Analysis of the second stage SFA regression results

Relaxation variables of input indicators obtained in the first stage, namely fixed assets relaxation variable, employee number relaxation variable and operating cost relaxation variable, were taken as dependent variables, and 3 environmental variables were taken as independent variables. SFA regression analysis was conducted to measure the influence of 3 environmental factors variables on 3 input relaxation variables. The results are shown in Table 1 below. Through the significance test analysis of the SFA regression results in the second stage, it is concluded that the LR value meets the significance level of 2.5%, indicating that the three environmental variables have a significant impact on the waste of operational input resources of the sample listed companies. The mean value is 0.92, approaching 1, indicating that there is interference of environmental factors on enterprise operation efficiency, and it can be predicted that the mixed error is basically dominated by management inefficiency. It also passes the significance test, which proves that it is more accurate and reasonable to conduct research and evaluation on the operating efficiency of sample listed companies after removing environmental variables, random influencing factors and management inefficiency. By improving the level of operation and management, enterprises reduce the investment in fixed assets, the number of employees and operating costs, so as to achieve the forefront of operation efficiency. The resources saved in this process are input relaxation variables. If the coefficient of the input relaxation variable is positive, it indicates that the environmental variable has the same influence on the input relaxation variable, that is, the increase of the environmental variable will lead to the increase of the resource waste of the input variable, and the operation efficiency of the enterprise will decrease accordingly. If the coefficient of the input relaxation variable is negative, it is proved that environmental factors have a reverse change effect on the input relaxation variable, that is, the increase of environmental factors helps to reduce the input variable resources, thus improving the operation efficiency.

According to Table 4, it can be found that government subsidies help enterprises to reduce investment in fixed assets and the number of employees, thus reducing the cost of human resources, but will increase operating costs to a certain extent and lead to waste. The reason may be that relevant policies issued by Shandong Province are gradually improving the production and research mechanism of enterprises and subsidies for talent introduction. Most enterprises can enjoy the preferential policy of additional deduction of R&D expenses, which helps enterprises to reduce the cost of investment in fixed assets. The increase of subsidies for talents will reduce the corresponding human cost input of enterprises, and the number of employees will be reduced to a certain extent, thus improving operation efficiency, and enterprises will invest more funds in production and sales. The inaccuracy of the business strategy leads to the increase of the operating cost, resulting in a certain degree of waste, which reduces the operating efficiency of the enterprise; The longer the establishment years of an enterprise will lead to an increase in the cost of updating fixed assets for internal production and operation. With the increase of listing years, the gradual development of the

enterprise will lead to an increase in the demand for internal staff talents. The increase of production and sales cost eventually leads to the increase of operating cost and waste; Generally speaking, enterprises in areas with high per capita GDP usually have higher technical level, more developed modern service industry and manufacturing industry, while enterprises in areas with low per capita GDP usually rely on traditional industries and resources. Most of the talents flow into the regions with more developed GDP, which may lead to the excess and waste of human resources in the region, resulting in the unbalanced distribution of human resources in provinces and cities. Enterprises in regions with high GDP generally have sufficient financial support. Since listed companies need a certain period of time to explore product research and development or service provision in the initial stage of operation, they may blindly invest resources in R&D and production activities of enterprises, resulting in waste of fixed assets and other resources and corresponding increase in operating costs. Thus reducing the operating efficiency of enterprises.

Table 4. Results of variable SFA regression analysis of sample enterprises

Project	Fixed assets relaxation variable	Employee slack variable	Operating cost slack variable
Constant term	-0.0518	-0.0421	-0.0286
Government subsidy	-0.0038	-0.0007	0.0256
Establishment years of enterprises	0.0228	0.0351	0.0162
Municipal GDP per capita	0.0004	0.0064	0.0009
σ^2	0.0067	0.0040	0.0026
γ	0.9200	0.9500	0.9280

5.3. Third stage: Analysis of adjusted DEA model results

5.3.1 Comparison of Business Efficiency

The comparison of operational efficiency between the first and third stages of the sample enterprises is shown in Table 5. After excluding environmental and random interference factors, the number of enterprises with a comprehensive efficiency of 1 increased from 3 in the first stage to 4 in the third stage. The number of enterprises at a relatively strong level has risen from 15 to 170; The number of enterprises at the average level has decreased by 71; The number of enterprises below the average level has reduced from 85 to 0. The number of enterprises with pure technical efficiency equal to 1 has decreased from 8 in the first stage to 7 in the third stage. The number of enterprises at a relatively strong level has increased from 21 to 177; The number of enterprises at the average level has decreased by 86; The number of enterprises below the average level has reduced from 69 to 0. The overall level of scale efficiency is still relatively high, with the number of enterprises at or below the average level decreasing from 10 to 0. Compared to before adjustment, the overall improvement of the three efficiency values of the sample enterprises is significant, indicating that the external environment has limitations on the operational efficiency of listed companies in Shandong Province.

Table 5. Comparison of operating efficiency results between the first and third stages of sample enterprises

Enterprise operating efficiency level	Numerical range	TE		PTE		SE	
		Phase 1	Phase 3	Phase 1	Phase 3	Phase 1	Phase 3
Poor	<0.2	2	0	2	0	0	0
Weak	[0.2, 0.5)	83	0	67	0	0	0
Medium	[0.5, 0.8)	86	15	91	5	10	0
Secondary Strong	[0.8, 1.0)	15	170	21	177	176	185
Strong	1	3	4	8	7	3	4

5.3.2 Analysis by Industry

(1) Comparison of Operating Efficiency Results of Sample Enterprises before and after Industry Adjustment is shown in table 6, After excluding the influence of environmental factors and random errors, various industries' comprehensive efficiency and pure technical efficiency have significantly increased, indicating a poor operating environment for enterprises. The comprehensive efficiency and pure technical efficiency of public management and social organizations, manufacturing, agriculture, forestry, animal husbandry, fisheries, mining, residential services and other service industries, transportation, warehousing, and postal services have significantly improved, indicating that environmental factors have strong constraints on these six industries; At the same time, the scale efficiency of information transmission, computer services, and software industry, public management and social organizations, resident services and other service industries, and construction industry has decreased, indicating that the scale efficiency of these four industries has been overestimated.

(2) Except for the financial industry, real estate industry, information transmission, computer services and software industry, culture, sports and entertainment industry, the overall efficiency of other industries is below 0.9, which is at an average level. Among them, the comprehensive efficiency of the production and supply of electricity, gas, and water, construction, transportation, warehousing, and postal industries is in the bottom three, and there is still significant room for improvement.

Table 6. Comparison of Operating Efficiency Results of Sample Enterprises before and after Industry Adjustment

Industry	Quantity	Phase 1			Phase 3		
		TE	PTE	SE	TE	PTE	SE
Finance	2	0.822	0.949	0.840	0.992	0.996	0.995
Real estate	4	0.854	0.878	0.971	0.958	0.982	0.975
Information transmission, computer services, and software industry	7	0.658	0.675	0.974	0.924	0.961	0.962
Culture, sports and entertainment	3	0.601	0.627	0.955	0.902	0.925	0.976
Wholesale and retail	7	0.632	0.668	0.950	0.899	0.928	0.967
Public management and social organizations	1	0.511	0.532	0.964	0.884	0.980	0.901
manufacturing	147	0.525	0.563	0.944	0.884	0.915	0.966
Agriculture, forestry, animal husbandry and fishery	4	0.292	0.389	0.876	0.880	0.922	0.954
Mining	3	0.527	0.676	0.807	0.874	0.889	0.982
Residential services and other service industries	1	0.474	0.478	0.991	0.861	0.948	0.908
Production and supply of electricity, gas, and water	2	0.623	0.705	0.895	0.859	0.887	0.969
Construction	3	0.685	0.730	0.940	0.837	0.938	0.889
Transportation, storage, and postal services	5	0.498	0.594	0.879	0.836	0.871	0.962

5.3.3 Analysis by Region

Divide the sample enterprises by region, and the specific ranking and average efficiency results are shown in Table 7. The results show that the comprehensive efficiency and pure technical efficiency of various regions in Shandong Province have significantly increased, with most areas experiencing a slight increase in scale efficiency and a few regions experiencing a slight decrease in scale efficiency. This indicates that the significant upward fluctuation in pure technical efficiency is the main reason for improving the operational efficiency of listed companies in various regions. Specifically, the comprehensive efficiency of Tai'an City, Heze City, and Jinan City is at a leading level before and after the adjustment, indicating that the market environment in these areas is

relatively good. Therefore, the operating efficiency is relatively high. It is worth noting that the comprehensive efficiency rankings of Zaozhuang City and Linyi City have decreased significantly after adjustment, with Zaozhuang City dropping from 3rd to 15th and Linyi City dropping from 6th to 13th. This indicates a phenomenon of high efficiency in Zaozhuang City and Linyi City under the influence of environmental factors and random errors. The comprehensive efficiency ranking of Weifang City has significantly increased after adjustment, rising from 13th to 5th, indicating that there is still significant room for improvement in the operational efficiency of listed companies in the region.

Overall, after adjusting for input variables, the comprehensive efficiency and pure technical efficiency of listed companies in Shandong Province increased by 61.25% and 58.08%, respectively, from 2018 to 2022. Still, the scale efficiency slightly increased by 1.26%. This result indicates that pure technical efficiency is currently the main factor affecting the operational efficiency of listed companies in Shandong Province, which also suggests that listed companies in Shandong Province have waste or poor resource utilization management problems.

Table 7. Comparison of operating efficiency values among 16 cities in Shandong Province before and after adjustment

Industry	Phase 1				Phase 3			
	Rank	TE	PTE	SE	Rank	TE	PTE	SE
Tai'an City	1	0.726	0.748	0.971	1	0.939	0.966	0.972
HeZe City	2	0.666	0.688	0.968	2	0.908	0.929	0.977
Zaozhuang City	3	0.663	0.678	0.969	15	0.847	0.938	0.904
Jinan City	4	0.620	0.675	0.929	3	0.902	0.927	0.973
Qingdao City	5	0.591	0.644	0.928	6	0.889	0.922	0.964
Linyi City	6	0.557	0.576	0.969	13	0.864	0.919	0.940
Yantai City	7	0.543	0.584	0.941	4	0.891	0.928	0.961
Dongying City	8	0.541	0.576	0.943	8	0.885	0.908	0.976
LiaoCheng	9	0.514	0.564	0.931	9	0.882	0.911	0.967
Zibo City	10	0.504	0.541	0.942	7	0.888	0.913	0.972
Binzhou City	11	0.501	0.516	0.972	12	0.873	0.908	0.962
Dezhou City	12	0.499	0.536	0.943	14	0.852	0.878	0.971
Weifang City	13	0.476	0.526	0.932	5	0.889	0.922	0.963
Weihai City	14	0.453	0.483	0.946	10	0.874	0.912	0.959
Jining City	15	0.439	0.489	0.927	11	0.873	0.903	0.967
Rizhao City	16	0.376	0.384	0.980	16	0.735	0.763	0.969
mean value	-	0.542	0.575	0.950	-	0.874	0.909	0.962

6. Results and recommendations

Firstly, although the operational efficiency of listed companies in Shandong Province has generally reached a moderate or above level, there is still significant room for improvement. From the data of the sample companies, only four companies (accounting for 2.12%) have achieved the best effective operating efficiency, indicating that most companies still have significant room for operational quality and efficiency improvement. To this end, enterprises and governments should jointly take measures to strengthen regular evaluations of enterprise operations, conduct in-depth analysis of market trends, and enhance professional training and skill enhancement for employees to promote the overall efficiency of enterprise operations.

Secondly, the operational efficiency of listed companies in Shandong Province is largely limited by pure technical efficiency. Enterprises can improve their pure technological efficiency through various means, such as international cooperation and technology introduction, to obtain advanced technology and management experience. At the same time, investment in independent research and

development in critical technologies and core products should be increased to enhance the core competitiveness of the enterprise. Optimize production and operational processes, apply automation technology in production and management processes, such as using robots for automated production, artificial intelligence, and big data technology for market analysis and decision support, and improve work efficiency and accuracy. In addition, establishing a scientific human resource management system, such as implementing performance management, planning career development paths, and designing effective employee incentive mechanisms, can improve employee work efficiency.

Thirdly, environmental factors significantly impact the operational efficiency of listed companies in Shandong Province, and the operating environment needs further improvement. The government should introduce more policies conducive to the development of enterprises, such as tax reductions, providing financial subsidies and preferential loans, to reduce the operating costs of enterprises and stimulate innovation investment. At the same time, it is necessary to pay attention to the balance of regional development, primarily by increasing support for economically underdeveloped areas, providing essential financial and technical assistance, and promoting the balanced development of the regional economy. In addition, improving infrastructure, such as increasing investment in transportation, communication, and other areas, can enhance enterprises' logistics and information communication conditions, creating a better external operating environment.

Fourthly, the government can take targeted measures to address the significant differences in operational efficiency among listed companies in different industries and regions. Based on the characteristics and needs of various industries, provide professional policy guidance and technical support to help enterprises overcome industry-specific difficulties. At the same time, they are promoting economic cooperation and resource sharing among different regions, establishing regional economic coordination mechanisms, and improving the economic efficiency and competitiveness of the entire region through resource integration and complementary advantages. Based on the specific situation of each region and industry, formulate differentiated development strategies and policy support to ensure the accuracy and effectiveness of policies, thereby promoting balanced development of each region and industry.

References

- [1] Peng Leiyi, Luo Jianji, Xiao Honggen, et al. Study on the operating efficiency of residential accommodation industry based on three-stage DEA model: A case study of Hangzhou [J]. Tourism BBS, 2022, (4): 69-82.
- [2] Wang Xinyi. Business Performance Evaluation of Listed Companies based on DEA model -- A case study of Hefei City [J]. Journal of Anhui Vocational and Technical College, 2019, 22 (04): 32-37.
- [3] Cui Mingfeng. Research on operation efficiency of listed commercial banks in China based on three-stage DEA-Tobit [D]. Hebei university of geosciences, 2022.
- [4] Wu Zongze, Song Liangrong. Listed Chinese logistics enterprises operating efficiency based on DEA model evaluation [J]. Journal of technology and innovation management, 2023, 44 (02): 169-179.
- [5] Yin Yue. Research on Influencing Factors of operating efficiency of property insurance companies under the background of Internet [D]. Zhejiang university, 2019.
- [6] Li X. Research on influencing factors of operating efficiency of listed tourism companies based on DEA [D]. Hainan tropical Marine institute, 2023.
- [7] Bi Xiaolei. Research on Operating efficiency and its Influencing Factors of listed advertising companies in China [D]. Shandong university, 2023.
- [8] Wang Yuting. Research on Management efficiency of listed cultural media enterprises and its influencing factors [D]. Nanjing university of posts and telecommunications, 2023.
- [9] Li Wei. Relative Effectiveness Evaluation of operating efficiency of listed publishing and media companies: Based on data envelopment analysis [J]. Science and Technology for Development, 2019, 19 (12): 776-784.

- [10] Wang Huiyan, Lian Jiliang. Based on new energy wind power manufacturing enterprises of the three-stage DEA efficiency evaluation [J]. Modern industrial economy and information technology, 2023, 13 (11): 238-241.
- [11] Gong Mingyan. Analysis of operating efficiency of listed expressway enterprises in China based on DEA-Malmquist model [J]. Storage and transportation in China, 2024 (4): 141-142. The
- [12] Li Zhongshi, Wen Hua. Research on efficiency measurement of China's listed banks under the background of Internet finance [J]. Economic Research Guide, 2023 (16): 94-100.
- [13] ZHANG Liangyong, Li Yijia, Dong Bing. Evaluation of operational efficiency in the transformation of Chinese traditional automobile listed companies: An empirical study based on DEA-Tobit model [J]. Journal of Science and Technology Entrepreneurship, 2019, 36 (07): 58-62.
- [14] Tian Xiaoli, Wang Zhifang, Liu Zhengyong. Empirical research on the operational efficiency of Private banks in China: An analysis based on DEA and Malmquist index model [J]. Heilongjiang Finance, 2023 (09): 62-67.
- [15] Xu Huifang. Automobile manufacturing enterprises based on DEA efficiency evaluation and improvement [D]. Tianjin commercial university, 2023.