Evaluation of Operating Efficiency of Small and Medium Sized Technology Enterprises based on DEA Model：A Case Study of Jiangsu Province

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ABSTRACT
In recent years, Jiangsu Province has introduced a series of support policies to help small and medium-sized technology enterprises flourish, and also provide impetus for the economic development of Jiangsu Province. Using DEA model, this paper provides a scientific evaluation of the operational efficiency of 10 Jiangsu small and medium sized technology enterprises. The results show that: most of enterprises have significantly increased their operating efficiency, but the growth rate of business operating efficiency has decreased and improving the scale efficiency is the key to improve the enterprises operation efficiency.

Keywords: *Operating Efficiency; Small and Medium Sized Technology Enterprises; DEA Model; Jiangsu Province*

1. INTRODUCTION

Small and medium sized technology enterprises have high technology content and strong innovation capabilities, they are the main body of innovation with great vitality and potential. They contribute more than 60% of GDP and are an important force in promoting economic development. Operational efficiency is an indicator used to measure the operation of an enterprise. Efficient management contributes to improve operational performance of the business and helps the business to meet its short term liabilities effectively [1]. Therefore, this paper analysis that how small and medium sized technology enterprises attain an optimum level and provide insights into the future development of such enterprises and policy implementation.

2. LITERATURE REVIEW

2.1. Small and Medium Sized Technology Enterprises

According to the "Evaluation Measures for Small and Medium Sized Technology Enterprises" in May 2017, a small and medium sized technology enterprises must meet the following conditions: registered in China (excluding Hong Kong, Macao and Taiwan) resident enterprises; the total number of employees does not exceed 500, annual sales revenue does not exceed 200 million yuan, total assets do not exceed 200 million yuan; the products and services provided by the enterprise does not belong to the state regulations prohibitions, restrictions and elimination category; the enterprise in the previous year and the current year did not occur in a major safety, major safety, quality accidents and serious environmental violations, research and development; no quality accidents and serious environmental violations, scientific research serious breach of trust, and the enterprise is not listed in the business exception list and the list of serious violations and breach of trust; the enterprise according to the evaluation indicators of small and medium-sized technology enterprises for comprehensive evaluation of the score of not less than 60 points, and the score of technology personnel indicators shall not be 0 points.

The emergence of small and medium-sized technology enterprises is the product of the further introduction and implementation of science and technology policies. In small and medium-sized technology enterprises, technological innovation is the key to maintain good market performance and survival and development of the enterprise, and is also its most important social responsibility.

2.2. Operating Efficiency

In the context of deepening the investment system reform and transforming the development mode in China, various industries are paying more and more attention to operational efficiency. Zheng Minggui et al. studied the impact of private capital entry on the operating efficiency of energy enterprises based on DEA-Tobit model [2]. Yi Xingfei studied the delisted enterprises of Anhui Province New Third Board to explore the changes of their operational efficiency and successfully identified the reasons for the linear decline of operational efficiency [3]. Wang Jiao et al. studied the efficiency of listed military enterprises in China [4] . Wang Chia Nan et al. evaluated and predicted the performance of listed real estate enterprises in Vietnam based on the data envelopment analysis [5]. José F.M. Pessanha et al. propose a more robust approach to evaluate the regulatory operating expenses of transmission firms, using several different DEA models and then defining a global efficiency score based on the geometric mean of the DEA model [6]. Pablo Coto-Millán et al studied the impact of "cargo effect" on the technical efficiency and scale efficiency of air transportation [7]. However, for small and medium sized technology enterprises, most researchers mainly focus on the study of financing efficiency [8-9], but there are few articles focus on the operational efficiency of small and medium sized technology enterprises after receiving financing and government support.

The uniqueness of this paper is to build an evaluation model based on DEA model to study the operating efficiency of small and medium sized technology enterprises, and investigate the main factors affecting the operating efficiency. As a large economic province, Jiangsu Province cannot achieve the cultivation of new dynamic energy and promote industrial transformation and upgrading without the healthy development of the small and medium sized technology enterprises. Therefore, the evaluation can not only provide insight into the current enterprises operational efficiency, speculate on the factors influencing the operational development of Jiangsu small and medium sized technology enterprises, but also provide some reference for the formulation of relevant industrial policies in Jiangsu.

3. EVALUATION MODEL OF OPERATIONAL EFFICIENCY

Based on the concept of relative efficiency, DEA method is a non-parametric statistical method to evaluate the effectiveness of the same type of multi-input and multi-output decision-making units. It is mainly divided into CCR model and BCC model. According to the characteristics of BCC and CCR, this paper adopts the BCC model "with variable returns to scale" proposed by Banker et al. [10] and Charnest et al. to measure the initial input-output data for DMU technical efficiency [11]. The equation is as follows:

$$\min[\theta-\varepsilon(\hat{e}^{T} s^{-}+e^{T}s^{+})]$$

$$\begin{cases} \sum_{j=1}^{n} x_j\lambda_j + s^{-} = \theta x_0 \\ \sum_{j=1}^{n} y_j\lambda_j - s^{+} = y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0,\ j = 1,2,...,n,\theta \end{cases}$$

In the above formula, suppose θ^{*} , λ^{*} , s^{*+} , s^{*-} represents the corresponding input and output of DMU_0 in the optimal solution of BCC model. If $\theta^{*}=1$, $s^{*+}=0$, $s^{*-}=0$, the small and medium sized technology enterprises are DEA valid; if only $\theta^{*}=1$, but $s^{*+}\neq 0$ and (or) $s^{*-}\neq 0$ the medium sized technology enterprises is weakly DEA valid; and if any of the conditions in $\theta^{*}=1$, $s^{*+}=0$ and $s^{*-}=0$ are not established, the small and medium sized technology enterprises are DEA invalid.

4. EMPIRICAL RESULTS AND ANALYZATION

4.1. Data Source and Variables

In order to evaluate the operation efficiency of small and medium sized technology enterprises in Jiangsu Province, after excluding the enterprises that do not disclose relevant data, this paper takes 10 listed Jiangsu small and medium sized technology enterprises as the research object, searches the company's annual reports from 2018 to 2020, and obtains relevant data on the selected input and output indicators.

Since the data of individual enterprises is negative, the obtained relevant indicator data is processed without dimension, so that all indicator data are in the range of [0.1,0]. On the one hand, this data processing method satisfies the data requirements of the DEA model, on the other hand, it does not change the meaning of the data and the running results.

In the past, scholars would choose different index systems according to the different evaluation subjects and evaluation objectives when evaluating the operational efficiency of enterprises. Zou Qian et al. [12] selected input indicators in the process of studying the operating efficiency of petrochemical enterprises: main business cost, net value of fixed assets and the number of personnel, and output indicators for the main business

income. This paper is based on previous research and combines the actual situation, constructs the operating efficiency evaluation index system of small and medium sized technology enterprises, as shown in Table 1.

Table 1. Index System of Operating Efficiency Evaluation of Small and Medium Sized Technology Enterprises

Categories	Specific variables
Input Indicators	Non-current assets / million
	Technician/person
	Number of employees/person
Output Indicators	Operating costs / million yuan
	Operating income / million yuan
	Net profit / million

Non-current assets are the short-term unrealizable or consumable assets of the enterprise; the number of technical personnel is the number of personnel engaged in R&D work; the number of employees is the number of all employees in the workforce, reflecting the size of the enterprise; the operating cost is the number of employees in the enterprise; the number of employees is the number of all employees in the workforce, reflecting the scale of the enterprise; the operating cost is an indicator of capital and other inputs in the business process; the output indicators operating income reflects the enterprise operating income before subtracting various costs; net profit reflects the annual net profit of the enterprise, which is used to measure the annual operation of the enterprise.

4.2. DEA Static Analysis

Using the DEA-BCC model, this paper analyzes the sample data of 10 Jiangsu small and medium sized technology enterprises from 2018 to 2020, and obtains the operation evaluation results of technology listed companies, as shown in Table 2.

Table 2. 2018-2020 Operating efficiency of 10 Listed Enterprises in Jiangsu Province

Firm Code	2018	2019	2020
836908	0.892	0.938	0.901
872129	0.968	0.955	0.939
872941	0.987	0.985	0.936
838165	1	1	0.951
836329	1	0.949	0.952
871664	1	1	1
834440	0.978	0.939	0.982
836212	1	1	1
873006	1	1	1
836935	1	1	1

In terms of time change, the number of listed companies that achieve effective operating in the technology industry is decreasing year by year. From the perspective of a single listed company, all of them have a high comprehensive technical efficiency of 0.8-1. Huaxu Environmental, Jiayu Special Decoration, World Peace, and Little Cotton Jacket have a total comprehensive technical efficiency of 1, it means they have reached the forefront of comprehensive technical efficiency from 2018-2020. Qiaofa Technology, Insrude, He Ding Technology and Erikom are still not total comprehensive technical efficiency in these three years. Zhongyi Shares obtained lower comprehensive technical efficiency from 2020 and Baokun New Material obtained lower comprehensive technical efficiency from 2019.

According to the results of the DEA-BCC model, the comprehensive performance, pure technical efficiency and scale efficiency of 10 DMU in each year are calculated, and the average values are calculated respectively, as shown in Table 3.

Table 3. Mean Annual Operating efficiency of 10 Listed Enterprises in Jiangsu Province

Year	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Efficiency
2018	0.988	0.938	0.995
2019	0.994	0.983	0.939
2020	0.987	0.981	0.885
Mean	0.990	0.967	0.940

It can be seen from Table 3 that the average comprehensive technical efficiency remains between 0.9 and 1. During 2018-2020, the average comprehensive performance of enterprises shows a trend of first, rising and then, declining. In 2019, the value reaches the peak and then begins to decline. This shows that the comprehensive operating performance of Jiangsu small and medium sized technology enterprises is generally low, and the promotion is weak. The average value of pure technical efficiency is 0.967 and the average value of scale efficiency is 0.940. These indicates that the overall technical efficiency is caused by improper technology management, insufficient resource allocation, and failure to achieve scale effects. As for the change in tendency, comprehensive technical efficiency in 2018–2019 is increase, the reason is to reduce the pure technical efficiency, indicating that corporate management and resource configuration need to be improved. The reason for the 2019-2020's comprehensive technical efficiency decreases is a combination of reduced size and lower pure technical efficiency, indicating that the technology enterprises in this year did not developed well.

5. CONCLUSION

This paper uses a DEA model to measure the innovation performance of 10 listed Jiangsu small and medium sized technology enterprises from 2018 to 2020, the conclusions are as follows:

(1) In the past three years, most of the small and medium sized technology enterprises have significantly increased their operating efficiency, but the growth rate of business operating efficiency has decreased.

(2) The main reason for the decrease of comprehensive efficiency is the decrease of scale efficiency, so improving the scale efficiency is the key to improve the enterprises operation efficiency.

Based on the above conclusions, combined with the current development of Jiangsu small and medium sized technology enterprises, the following suggestions are put forward:

(1) At the government level, small and medium-sized enterprises and technology innovation must experience long-term investment to bring economic benefits. Enterprises face huge economic pressure from innovation activities, the government should continue to increase support for the development of small and medium sized technology enterprises.

(2) At the enterprise level, enterprises need to design a highly efficient organizational structure as well as communication and collaboration mechanism, introduce advanced management ideas and management methods, enhance hardware facilities, enhance the soft power of enterprise management and improve management efficiency.

(3) At the industry level, relevant departments and industry associations need to take measures to provide impetus for the upgrading of the science and technology industry. The small and medium sized technology enterprises should be stimulated to carry out technological innovation, strengthen the internal cooperation among regional enterprises, and jointly promote the collaborative development of technological progress and innovation of small and medium sized technology enterprises.

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