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# *Calculation and Analysis of Total Factor Productivity of Chinese Military Enterprises*

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***Abstract:*** Economic development is inseparable from the promotion of science and technology, and military enterprises are the main force in realizing technology transfer and transformation of scientific and technological achievements. This paper uses the static DEA-BCC model and the dynamic DEA-Malmquist model to statically and dynamically analyze the overall level of production efficiency of listed military enterprises from 2015 to 2020. The research results show that the production efficiency level of military industrial enterprises has made considerable progress in recent years, but it still needs to be further improved. On this basis, this paper puts forward policy suggestions from the aspects of optimizing resource allocation and management system.

## 1. Introduction

In October 2020, as my country's economic development gradually shifts from high-speed growth to high-quality development, the limited and scarce resources have determined that the economic growth model has been upgraded from a single factor-driven to an all-factor-driven and innovation-driven. As a national strategic industry, the national defense science and technology industry has the advantages of leading technology, abundant capital, complete facilities and abundant human resources, etc., and plays a very important role in promoting high-quality economic development and scientific and technological progress in my country. In 2015, the State Council issued "Made in China 2025" to promote in-depth innovation in the manufacturing industry, improve quality and efficiency, and further achieve the strategic goal of making a country strong. development pattern. under such a circumstance, This paper takes the list of military enterprises announced by the National Defense and Military Industry Section of the Military Industry Committee of the China Association of Listed Companies in 2015 as the research object, and takes 2015-2020 as the observation period, using the DEA-Malmquist index to dynamically investigate the production efficiency of my country's military industrial enterprises, in order to provide information for the military industry. Provide a reference for enterprises to better improve production efficiency.

## 2. Theoretical analysis and research hypothesis

From the literature review, it is found that domestic and foreign scholars have done a lot of related research on the efficiency of military enterprises. In the 1980s, Melman argued that the lack of competitive contracts for defense products in the military industry made inefficiencies and even inefficiencies a feature of the military industry. Parkera and Hartley (2002) took British military enterprises as the research object, and found that British defense enterprises have low production efficiency from the perspective of enterprise nature. At the same time, Lee (2009) found that market competition, capital gains, and the company's own R&D investment are important influencing factors among the many factors that affect the production efficiency of state-owned enterprises. In domestic research, Du Renhuai (2006) believes that the operational efficiency of China's defense science and technology industry is the core of the reform in the process of reform and development of the defense science and technology industry. Wu Qing (2007) found from the perspective of empirical research that factors such as market traction and clarity of property rights are important factors that affect the operational efficiency of military enterprises. Studies by Hu Hongan and others believe that the efficiency of military industry is closely related to its geographical location. Zhang Xu (2013) and others used the stochastic frontier method (SFA) to evaluate the production efficiency of my country's military enterprises, and found that my country's military enterprises as a whole are inefficient. Zhang Yong et al. (2014) studied the resource allocation of listed military enterprises in western my country by region, and found that their efficiency needs to be further improved and improved.

From the existing research, it can be found that there are many studies on the development status of my country's military enterprises from a static perspective, but there are certain deficiencies in the analysis of dynamic effects. At the same time, it can be found that the research sample is aimed at more than 20 enterprises belonging to the top ten military industrial groups, and the sample range is relatively small. Therefore, in view of the shortcomings of the existing research, this paper takes the list published by the China Association of Listed Companies as the research object, and conducts a dynamic investigation of its production efficiency, so as to provide reference for the better development of military enterprises.

## 3. Evaluation model construction

### 3.1. DEA-BCC model

Data Envelopment analysis (DEA) is a non-parametric system analysis method based on linear programming to evaluate the relative effectiveness of multi-input and multi-output decision making units of the same type, which belongs to the field of interdisciplinary research of operations research, management science and mathematical economics.Data envelopment analysis method to study the efficiency of scientific research in higher educational institutions has applicability, is able to handle most of the multiple output decision-making unit evaluation, and dimension there is no requirement for input and output index, index weight is calculated through science, ruled out the subjectivity of human empowerment, to some extent to ensure the evaluation results more comprehensive and scientific and reasonable .In order to more comprehensively analyze the change of scientific research level in colleges and universities, this paper adopts DEAA-BBC model to measure the innovation efficiency of scientific research in colleges and universities. The model set in this paper is as follows:

Suppose there is a number of colleges and universities s, each college has m types of input and n types of output, $DMU_j$ represents the j college, $X_j$ and $Y_j$ represent the input and output respectively.That is:

$$X_j = (x_{1j}, x_{2j}, \dots \dots, x_{mj})^T \tag{1}$$

In Formula (1), $x_{ij}>0$ represents the input amount; i = 1, 2, ..... ,m ; j = 1, 2,..., s.

$$Y_j = (y_{1j}, y_{2j}, \dots \dots, y_{nj})^T \tag{2}$$

In Formula (2), $y_{rj}>0$ represents the output; r = 1, 2,..., n.The model to evaluate the efficiency of the j is:

$$\min[\theta - \varepsilon\left(e^T s^- + \overset{\wedge T}{e} s^+\right)]$$

$$\text{s.t}\begin{cases}\sum_{j=1}^{s} \lambda_{jx_j} + s^+ = \theta X_p \\ \sum_{j=1}^{s} \lambda_{jx_j} - s^- = Y_p \\ \lambda_j \geq 0, j = 1,2,\dots,s \\ \sum_{j=1}^{s} \lambda_j = 1 \\ s^+, s^- \geq 0\end{cases} \tag{3}$$

In Equation (3), θ represents the efficiency evaluation value; ε represents the non-Archimedean infinitesimal parameters introduced in the model; $\lambda_j$ represents the parameter of the decision unit. $X$ is innovation factor input of p , $Y$ is innovation output, $s^+$and $s^-$ are slack and redundant variables of input-output. When θ= 1, the DMU is weakly efficient. When θ<1, DEA is not effective. When θ=1, $s^+ = 0$, $s^- = 0$, DEA is valid.

## 3.2. Malmquist index

Malmquist index is an index proposed by Malmquist to calculate consumption, which can carry out dynamic efficiency analysis on objects with multi-input and multi-output structure, and consists of technological progress efficiency (Tech), pure technical efficiency (Pe) and scale efficiency (Se). The expression formula of the Malmquist index is as follows:

$$\text{Techch} = \left[\!\left[\frac{D^t(x_{t+1,}y_{t+1})}{D^{t+1}(x_{t+1,}y_{t+1})} \times \frac{D^t(x_{t,}y_t)}{D^{t+1}(x_{t,}y_t)}\right]\!\right] \tag{4}$$

$$\text{Effch} = \frac{D^{t+1}(x_{t+1,}y_{t+1})}{D^t(x_{t,}y_t)} \tag{5}$$

Technological progress (Techch) in Formula (4) and technological efficiency change (Pech) in Formula (5) are decomposition terms of technological efficiency change.

## 3.3. Index selection and data sources

In the process of industrial activities, it is necessary to input different element resources, such as human resources, financial resources, material resources, etc. The input of resources is a prerequisite for efficient output. At the same time, according to the theory of production factors, capital and labor are the keys to determine the size of potential production capacity, and operating income is the indicator that can most directly reflect the output status of an enterprise. Therefore, on the basis of learning from domestic and foreign research, the principles of typicality, comparability, and operability of index construction are considered, and at the same time, data availability and source reliability are considered. Index Construction Establish the index system of this paper. As shown in Table 1.

Table 1: Total Productivity Indicators of Military Industrial Enterprises

| indicators | The indicator system |
|---|---|
| Input indicators | Total number of employees (person)<br>Net fixed assets (yuan) |
| Output indicators | Operating income (yuan) |

The choice of input indicators. Input indicators mainly include human resources and financial resources of military enterprises. As the core elements of enterprise development investment, capital and labor have a relatively important position and decisive significance. In terms of labor input, most scholars used to measure the number of employees at the end of the year. Taking into account the availability of data from military enterprises, this paper draws on the practice of scholars such as Zhang Ming and selects the total number of employees as the labor input indicator. In terms of capital investment, we refer to the practice of most scholars and choose to use the net fixed assets of military enterprises as a measure.

Choices on output indicators. Operating income, as a direct result of market position, is a good reflection of the dual effects of output and competition. On the basis of learning from Zhang Yong and other scholars, this paper chooses operating income as the output indicator of military enterprises.

The data required for the input and output of this paper are all from the CSRM financial database. The 98 companies announced by the China Association of Listed Companies are used as decision-making units, and deap2.1 is used to calculate the efficiency value of listed military enterprises in 2015-2020.

## 4. Empirical results and analysis

### 4.1. Static analysis of university scientific research innovation performance based on DEA-BCC model

Through the collected data, the BCC model and deap2.1 are used to measure the production efficiency of 98 listed military enterprises from the output-oriented variable scale return. The calculated average comprehensive technical efficiency, pure technical efficiency, and scale efficiency are taken as the annual efficiency values, the results are shown in Table 2.

Table 2: Annual efficiency value of listed military enterprises from 2015 to 2020

| year | technical efficiency | pure technical efficiency | scale efficiency |
|---|---|---|---|
| 2015 | 0.125 | 0.322 | 0.425 |
| 2016 | 0.244 | 0.663 | 0.435 |
| 2017 | 0.229 | 0.361 | 0.703 |
| 2018 | 0.234 | 0.344 | 0.750 |
| 2019 | 0.232 | 0.341 | 0.735 |
| 2020 | 0.258 | 0.353 | 0.795 |
| mean | 0.220 | 0.397 | 0.647 |

According to the calculation logic of the BCC model, when the efficiency value is close to or equal to 1, it means that the productive frontier has been reached, and the efficiency is high, and when the efficiency value is lower than 1, it means that the gap with the frontier is large. From Table 2, it can be seen that the average value of technical efficiency, pure technical efficiency or scale efficiency of 98 military enterprises from 2015 to 2020 is less than 1, indicating that the production efficiency of my country's military enterprises needs to be further improved. Specifically in:

The average scale efficiency from 2015 to 2020 is 0.647, the average pure technical efficiency is 0.397, and the average comprehensive technical efficiency is 0.220, all of which are at a low level, and the comprehensive technical efficiency is the lowest among the three efficiencies. But from the side, it can also show that there is a lot of room for improvement in the production efficiency of my country's military industrial enterprises, the technical level of the enterprises needs to be further improved, and the management system needs to be further improved.

### 4.2. Dynamic analysis of university research innovation performance based on Malmquist index

On the basis of using the DEA-BCC model to measure the static efficiency of scientific research performance of colleges and universities in the Chengdu-Chongqing area above, the Malmquist index is used to further measure the dynamic changes in the production efficiency of listed military enterprises from a dynamic perspective from 2015 to 2020 (Table 3, Table 4). In terms of dynamic changes, the overall level of production efficiency of 98 military industrial enterprises from 2015 to 2020 was relatively low. And it can be found from the figure that there is a relationship between comprehensive technical efficiency, technological progress, scale efficiency and total factor productivity, and each efficiency value gradually tends to be stable from fluctuations.

(1) Overall efficiency analysis

During the sample observation period, the proportion of military enterprises with total factor productivity greater than or equal to 1 accounted for 78.57%, indicating that the productivity of the entire industry was at a high level from 2015 to 2020. Judging from the technical efficiency index and technological progress index that cause changes in total factor productivity, nearly 72.72% of the enterprises with pure technical efficiency index are greater than or equal to you, indicating that the restructuring of military enterprises in recent years has promoted their resource allocation capabilities and resource utilization efficiency; The technological progress index is basically less than 1, but it also shows that technological progress has not played an effective role. Due to limited space, Table 3 only presents the relevant data of 10 companies.

Table 3: Average Malmquist Index and Decomposition of Military Enterprises in 2015-2020

| Securities code | effch | techch | pech | sech | tfpch |
|---|---|---|---|---|---|
| 000021 | 0.996 | 0.946 | 0.894 | 1.114 | 0.942 |
| 000026 | 1.131 | 0.943 | 1.019 | 1.109 | 1.066 |
| 000032 | 1.177 | 0.959 | 1.233 | 0.954 | 1.128 |
| 000050 | 1.126 | 0.884 | 1.019 | 1.105 | 0.996 |
| 000059 | 1.207 | 0.885 | 0.960 | 1.257 | 1.068 |
| 000065 | 1.000 | 0.892 | 1.000 | 1.000 | 0.892 |
| 000066 | 0.887 | 0.976 | 0.776 | 1.143 | 0.866 |
| 000519 | 1.378 | 0.872 | 1.102 | 1.251 | 1.201 |
| 000547 | 1.245 | 0.919 | 1.138 | 1.094 | 1.145 |
| 000550 | 1.213 | 0.895 | 0.989 | 1.227 | 1.086 |
| mean | 1.188 | 0.910 | 1.035 | 1.147 | 1.081 |

(2) Development dynamic analysis

As shown in Table 4, the overall technical efficiency showed a downward trend from 2015 to 2020. Among them, the changes in pure technical efficiency and scale efficiency from 2015 to 2016 are the direct reasons for the sharp decrease in comprehensive technical efficiency, which also shows that the resource allocation efficiency and production efficiency of military industrial enterprises are at a low level. The average value of pure technical efficiency in 2015-2020 was 1.035, which is an important factor to promote the efficiency improvement of military enterprises, but it showed a fluctuating downward trend in 2015-2020.

From the perspective of development trends from 2015 to 2020, as shown in Figure 1, the overall technological progress of military enterprises showed a trend of rising first and then falling, while the overall technical efficiency and total factor productivity showed a trend of first falling and then rising. The trends of total factor productivity and comprehensive technical efficiency are basically the same, but the degree is different, while technological progress shows the opposite characteristics, indicating that technological progress does not play a leading role in the total factor productivity of military enterprises, and it is necessary to further think about its internal reasons.

Table 4: Average annual Malmquist index and decomposition from 2014 to 2018

| year | Effch | Techch | Pech | Sech | Tfpch |
|---|---|---|---|---|---|
| 2015-2016 | 2.177 | 0.499 | 1.138 | 1.913 | 1.086 |
| 2016-2017 | 0.957 | 1.095 | 1.044 | 0.916 | 1.048 |
| 2017-2018 | 1.008 | 1.080 | 0.954 | 1.056 | 1.089 |
| 2018-2019 | 1.000 | 1.105 | 1.013 | 0.987 | 1.105 |
| 2019-2020 | 1.126 | 0.956 | 1.035 | 1.088 | 1.077 |
| mean | 1.188 | 0.910 | 1.035 | 1.147 | 1.081 |

## 5. Conclusions and recommendations

Based on the panel data of 98 companies in the military sector published by the China Association of Listed Companies, this paper uses the static DEA-BCC model and the dynamic DEA-Malmquist model to empirically study the efficiency changes of 98 companies in the military sector from both dynamic and static aspects. The following conclusions: The productivity of military enterprises has been improved to a certain extent, but there are also certain deficiencies.

This paper puts forward the following suggestions: (1)Military enterprises should continuously improve their management level and establish an advanced modern enterprise management concept according to the characteristics of large scale, high risk, long cycle and high technology-intensive industries. (2)Military enterprises can continuously increase the intensity of scientific and technological innovation through mergers and acquisitions, and at the same time need to continuously strengthen their independent innovation capabilities.

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