# Comparison of Two University Scientific Research Performance Evaluation Models Based On DEA Method

**Fei Bian**

Institutional Research Center of Shenzhen Polytechnic, Shenzhen 518055, China

371247627 @qq.com

**Keywords:** DEA, university research performance, evaluation model

**Abstract:** In this study, the input and output data of scientific research in 64 universities directly under the ministry of education in China in 2017 were selected as research samples, the DEA method was applied to the evaluation of scientific research performance of universities, and the cross efficiency model of DEA and CCR model of traditional DEA method were used to evaluate the scientific research performance of the sample universities. Through comparative analysis, it is concluded that the DEA cross-efficiency model successfully overcomes the problem that the traditional CCR model can only be self-evaluated and has too many effective units; the scientific research performance of different universities is quite different, and the research performance of some universities is relatively low, and fail to make effective use of educational resources.

## 1. Introduction

The report of the 19th National Congress of the Communist Party of China explicitly stated: "Accelerate the construction of first-class universities and first-class disciplines, and realize the connotative development of higher education." This is a major strategic deployment of China's higher education in the new era, which is of extremely important significance to improve the development level of China's higher education and enhance the country's core competitiveness. In recent years, the state has continuously increased investment in research funding for universities. Scientific evaluation of the input and output of scientific research in universities is conducive to objectively understanding the scientific research level of Chinese universities, optimizing the allocation of resources, improving the efficiency of scientific research, and improving the quality of connotative development of higher education.

DEA (data envelopment analysis) is a method put forward by the famous operations researcher A. Charnes et al. to evaluate the relative efficiency between departments. The DEA method was first introduced by foreign scholars to evaluate the efficiency of teaching, scientific research and management in universities. Harris [1] measures the efficiency of scientific research in Australian universities in terms of both quantity and quality. Beasley et al. [2] used the DEA method to measure the different efficiency levels of research and teaching by dividing scientific research resources and teaching resources. Johnes [3] used the DEA method to study the thousands of graduates of several universities to evaluate the running efficiency of each university. Kao et al [4] used the DEA method to evaluate the school-running performance of different faculties and departments in Taiwan's successful universities through the data obtained, and analyzed the reasons for inefficiency. Liu et al. [5] extended the traditional DEA model to the fuzzy-determined domain DEA model and evaluated the operational efficiency of university libraries in Taiwan. Johnes et al [6] used the DEA method to evaluate the running efficiency of a college in a UK university, and comprehensively analyzed and determined the evaluation indexes of the faculties and departments. Reichmann and Sommersguter-Reichmann [7] used the DEA method to evaluate the efficiency of dozens of libraries in Austria, Canada and other countries.

Chinese scholars have also introduced the DEA method to evaluate the performance of teaching, scientific research and management in Chinese universities. Wang Xiaohong et al. [8] proposed a scientific research performance evaluation model based on DEA method and multi-index comprehensive evaluation method, which made a reasonable correction of traditional evaluation results, and compared and analyzed the output performance between different input scale units. Wang xiaohong et al. [9] found a positive correlation between the relative output of scientific research and the efficiency of scientific research through analyzing the efficiency of scientific research in two different periods in China, and improved the incentive system for scientific research, which can effectively stimulate the enthusiasm of scientific research personnel and help improve the efficiency of scientific research in universities. Yang Chuanxi et al. [10] used the DEA method to measure the efficiency of science and technology resource allocation in agricultural and forestry universities, and believed that the technical efficiency of agricultural and forestry universities in China has increased by 1.1 percentage points on average, and the efficiency of science and technology resource allocation has shown an upward trend, but there are certain differences between universities. Rao Wei et al. [11] evaluated the scientific research efficiency of universities in 31 provinces and cities nationwide by adopting the improved DEA method to establish an evaluation model with relatively lagging output. Lu Gensheng et al. [12] conducted DEA analysis on the technical efficiency, pure technical efficiency and scale efficiency of scientific research in universities directly under the Ministry of Education. It is considered that there are large fluctuations in different schools and the overall level needs to be further improved. Wang Lina [13] evaluated and analyzed the scientific research efficiency of 30 undergraduate universities in Jiangsu Province in 2007. It is considered that the scientific research efficiency of 12 universities in Jiangsu Province in 2007 is DEA effective, and the remaining 18 universities have input redundancy problems, there are insufficient output problems in the nine universities. Guan Xiaobin [14] combined with the second national R&D resource inventory data, and applied the data of colleges and universities in Beijing to conduct an empirical analysis, and considered that whether the central directly affiliated colleges have a significant impact on R&D input and output performance, and the universities directly under the central government does have certain advantages in terms of input-output efficiency and scale efficiency; the impact of high-level talents on input-output performance and technical efficiency is mainly reflected in the full utilization of R&D resources, thus realizing the optimal allocation of resources.

Although, Chinese scholars have done more research on the scientific research performance of universities and have obtained some meaningful results. However, the CCR model using the traditional DEA method has two defects in the evaluation of scientific research performance in Chinese Universities. First, using only a simple self-evaluation method, each DMU will automatically adjust its weight according to its own situation to make it beneficial to itself, but these weights may not be optimal for other DMUs. Second, the evaluation results of the traditional DEA method may result in simultaneous validity of multiple DMUs, and the scoring ranking of effective DMUs cannot be achieved.

Scientific evaluation of university research performance must consider that research is a complex system involving multiple inputs and multiple outputs. In order to solve the above problems, this study introduces a cross-evaluation mechanism, uses the DEA cross-efficiency model to evaluate the scientific research performance of the universities directly under the Ministry of Education, and compares and analyzes the results of the CCR model to some extent to make up for the shortcomings of the traditional DEA method and verify the DEA cross. The superiority of efficiency evaluation makes it more scientific and reasonable to evaluate the performance of scientific research in Chinese universities.

## 2. Evaluation index system and two evaluation models based on DEA method

### 2.1 Selection of evaluation index system

Scientific research performance refers to the conversion efficiency between input and output in scientific research in universities. Before the evaluation, we must first determine the indicators of scientific research input and output in universities. In this study, the following indicators were selected as the scientific research input and scientific research output indicators for scientific research performance evaluation. Among them, the selected scientific research input indicators include personnel input and funding input. By referring to the previous research results, and considering the availability of data, we selected two indicators of scientific and technological activities personnel, research and development personnel as personnel input indicators, and selected the appropriated funds as funds input. The publication of scientific and technological works, the publication of academic papers, and the actual income in the year of technology transfer are selected as indicators of scientific research output. The data adopted are from the compilation of science and technology statistics of institutions of higher learning in 2017 compiled by the department of science and technology of the ministry of education of the People's Republic of China.

**2.2 Selection of two evaluation models based on DEA method**

The DEA method is an evaluation method that uses a mathematical programming model to calculate the relative effectiveness of several decision making units (DMUs) with the same inputs and outputs. After continuous development and improvement, the DEA method has been applied to a wide range of fields by many scholars.

For n similar evaluation units with m inputs and s outputs, the i-th similar evaluation unit are $\mathrm{DMU_i}$ , and the m inputs are $\mathrm{x_i}(\mathrm{i} = 1,2,3 \ldots\ldots \mathrm{n})$ , respectively. The s outputs are$\mathrm{y_i}(\mathrm{j} = 1,2,3 \ldots\ldots \mathrm{n})$. For such problems, Charnes and Cooper proposed the CCR model in 1978, and evaluated the efficiency of each similar evaluation unit. The evaluation model is as follows:

$$\max \sum_{r=1}^{s} \mu_{rd}\, y_{rd} = \theta_d$$

$$s.t. \;\; \sum_{t=1}^{m} w_{id} x_{ij} - \sum_{r=1}^{s} \mu_r\, y_{rj} \geq 0$$

$$\sum_{i=1}^{m} w_{id} x_{id} = 1$$

$$w_{id} \geq 0, \qquad i = 1,2 \ldots\ldots m$$

$$\mu_{rd} \geq 0, \qquad r = 1,2 \ldots\ldots s$$

Where, $w_{id}$ and $\mu_{rd}$ represent the weights of input and output that can satisfy the above formula, and $\theta_d$ represents the efficiency value $E_{dj}$ calculated by each $DMU_i$ under the optimal weight of its input and output, and the calculation formula as follows:

$$E_{dj} = \frac{\sum_{r=1}^{s} \mu_{rd}^{*} y_{rj}}{\sum_{i=1}^{m} w_{id}^{*} x_{rj}}, \qquad d,j = 1,2 \ldots\ldots n$$

If the calculated $w_i$ and $\mu_i$ can make$E_{ii} = 1$, it can be said that this $DMU_i$ is valid for DEA; if E_ii<1, then this $DMU_i$ is valid for non-DEA. This discriminating method has two shortcomings which are most castigated by researchers. First, the weight used by this model to calculate the efficiency value of each $DMU_i$ is the most favorable for this $DMU_i$ itself, specifically, maximizing the weight of its own indicators, and minimizing the weights that are not conducive to its own indicators. It does not consider the influence of other decision-making units. This leads to a large difference in weights between input and output indicators. Therefore, it can be said that this model is an isolated and self-interested calculation of each $DMU_i$ efficiency value; second, this model calculates that there is more than one effective DMU of DEA, which makes it impossible to compare the effective DMUs of these DEA, and it is impossible to find defects between such DMUs.

In response to these two problems, Sexton et al. proposed a cross-efficiency model based on the traditional CCR model, which adopted the mutual evaluation system rather than the self-evaluation system, thus avoiding the self-calculation mode of CCR and calculating the efficiency value of each DMU in a more objective way. The specific model is as follows:

$$\max \sum_{r=1}^{s} \mu_r \, y_{rj} = E_{dj}^{*}$$

$$s.t. \quad \sum_{i=1}^{m} w_i x_{il} - \sum_{r=1}^{s} \mu_r \, y_{rl} \geq 0, l = 1,2 \ldots \ldots n$$

$$\sum_{i=1}^{m} w_i x_{ij} = 1$$

$$\sum_{i=1}^{m} w_i x_{id} - E_{dd} \sum_{r=1}^{s} \mu_r \, y_{rd} = 0$$

$$w_i \geq 0, \qquad i = 1,2 \ldots \ldots m$$

$$\mu_r \geq 0, \qquad r = 1,2 \ldots \ldots s$$

### 2.3 Selection of data processing tools

MATLAB (MATrix LABoratory) can realize matrix operations, and can also be used interactively with other databases and other languages, effectively saving development costs, shortening development time, and reducing the workload of system analysis. The DEA cross-efficiency model is constructed by using a matrix form, and the function library owned by MATLAB can operate on the matrix and quickly solve linear equation problems. Matlab is used to compile the evaluation program of DEA crossover efficiency model can effectively solve the problem of large computation and complexity caused by DEA cycle calculation.

## 3. Empirical research

### 3.1 Data source

Universities directly under the ministry of education play a leading role in China's higher education, and play a leading role in teaching, scientific research and social services. They are representative in terms of teaching, knowledge innovation and technology research and development. This study uses the "Compilation of Science and Technology Statistics of Universities in 2017" as the data source, and selects the statistical data of scientific and technological funds of universities directly under the ministry of education in 2017 as the research sample. Considering the unique educational orientation and discipline characteristics of some universities, such as the Central Academy of Fine Arts, the Central Academy of Drama, and the Central Conservatory of Music, they will not be included. Therefore, this study selected statistical data of 2017 science and technology in 64 universities directly under the Ministry of Education.

### 3.2 Empirical analysis

The DEA cross-efficiency model was used to evaluate the scientific research performance of 64 universities, and the results are shown in Table 1. For comparative analysis, we used the same data and evaluated it using the traditional CCR model. The results are shown in Table 2.

Table 1. Cross-efficiency scores of scientific research performance of universities directly under the ministry of education

| School name | Score | Ranking | School name | Score | Ranking |
|---|---|---|---|---|---|
| Fudan University | 0.973 | 1 | Beijing Normal University | 0.529 | 33 |
| Tsinghua University | 0.971 | 2 | Lanzhou University | 0.522 | 34 |
| Shanghai Jiaotong University | 0.915 | 3 | Tianjin University | 0.509 | 35 |
| China University of Mining and Technology (Beijing) | 0.877 | 4 | Donghua University | 0.501 | 36 |
| Communication University of China | 0.850 | 5 | Wuhan University | 0.497 | 37 |
| Hohai University | 0.848 | 6 | Chongqing University | 0.485 | 38 |
| Southwest Jiaotong University | 0.832 | 7 | China University of Petroleum (Beijing) | 0.472 | 39 |
| Ocean University of China | 0.815 | 8 | Peking University | 0.466 | 40 |
| Hefei University of Technology | 0.801 | 9 | Xi'an Jiaotong University | 0.460 | 41 |
| entral South University | 0.792 | 10 | Tongji University | 0.429 | 42 |
| Northeastern University | 0.783 | 11 | Northwest A&F University | 0.426 | 43 |
| Beijing Forestry University | 0.744 | 12 | China Agricultural University | 0.424 | 44 |
| Dalian University of Technology | 0.719 | 13 | Chang 'an University | 0.414 | 45 |
| Nanjing University | 0.717 | 14 | Sichuan University | 0.397 | 46 |
| Jiangnan University | 0.711 | 15 | North China Electric Power University | 0.375 | 47 |
| Beijing University of Traditional Chinese Medicine | 0.687 | 16 | Shandong University | 0.375 | 48 |
| Northeast Forestry University | 0.669 | 17 | People's University of China | 0.362 | 49 |
| Shaanxi Normal University | 0.659 | 18 | Nankai University | 0.361 | 50 |
| Huazhong Agricultural University | 0.641 | 19 | University of science and technology Beijing | 0.352 | 51 |
| Beijing University of Chemical Technology | 0.635 | 20 | University of Electronic Science and Technology | 0.342 | 52 |
| Southeast University | 0.622 | 21 | Xiamen University | 0.328 | 53 |
| Nanjing Agricultural University | 0.621 | 22 | China University of Geosciences (Wuhan) | 0.327 | 54 |
| Central China Normal University | 0.605 | 23 | Xi'an University of Electronic Science and Technology | 0.327 | 55 |
| Wuhan University of Technology | 0.604 | 24 | Southwest University | 0.321 | 56 |
| East China University of Science and Technology | 0.597 | 25 | Northeast Normal University | 0.319 | 57 |
| China Pharmaceutical University | 0.592 | 26 | Beijing Jiaotong University | 0.310 | 58 |
| China University of Mining and Technology | 0.584 | 27 | East China Normal University | 0.262 | 59 |
| Beijing University of Posts and Telecommunications | 0.572 | 28 | Hunan University | 0.261 | 60 |
| South China University of Technology | 0.547 | 29 | China University of Political Science and Law | 0.258 | 61 |
| China University of Geosciences (Beijing) | 0.541 | 30 | Sun Yat-sen University | 0.204 | 62 |
| Huazhong University of Science and Technology | 0.538 | 31 | China University of Petroleum (East China) | 0.137 | 63 |
| Zhejiang University | 0.534 | 32 | Jilin University | 0.113 | 64 |

As can be seen from Table 1, Fudan University, Shanghai Jiaotong University and other institutions of higher learning have better values, indicating that their scientific research performance is higher; Jilin University and China University of Petroleum (East China) higher education institutions have lower values, indicating their scientific research performance has not met the requirements, compared with Fudan University, Shanghai Jiaotong University and other universities, there is still much room for improvement.

Table 2. CCR scores of scientific research performance of universities directly under the ministry of education

| School name | CCR score | School name | CCR score |
|---|---|---|---|
| 25 universities including Tsinghua University | 1.000 | Hohai University | 0.731 |
| University of Electronic Science and Technology | 0.951 | Sun yat-sen university | 0.694 |
| North China Electric Power University | 0.932 | Sichuan University | 0.673 |
| Wuhan University | 0.912 | China University of Geosciences (Beijing) | 0.672 |
| Northeast Forestry University | 0.910 | Huazhong University of Science and Technology | 0.659 |
| Jiangnan University | 0.894 | Xi'an Jiaotong University | 0.648 |
| Wuhan University of Technology | 0.892 | Huazhong Agricultural University | 0.587 |
| Chongqing University | 0.882 | China University of Petroleum (Beijing) | 0.534 |
| Beijing University of Traditional Chinese Medicine | 0.871 | Hunan University | 0.516 |
| Ocean University of China | 0.832 | Shandong University | 0.502 |
| Beijing University of Posts and Telecommunications | 0.832 | University of science and technology Beijing | 0.496 |
| Beijing Forestry University | 0.823 | Beijing Jiaotong University | 0.473 |
| South China University of Technology | 0.815 | Xi'an University of Electronic Science and Technology | 0.452 |
| Shaanxi Normal University | 0.801 | Jilin University | 0.402 |
| Peking University | 0.801 | Southwest University | 0.397 |
| Central South University | 0.791 | China University of Petroleum (East China) | 0.386 |
| Northwest A&F University | 0.782 | Hefei University of Technology | 0.371 |
| Tongji University | 0.774 | Chang 'an University | 0.367 |
| Nanjing Agricultural College | 0.763 | Dalian University of Technology | 0.360 |
| Northeast Normal University | 0.753 | China University of Geosciences (Wuhan) | 0.357 |

As can be seen from Table 2, the efficiency values of 25 universities such as Tsinghua University are all 1, that is, they all belong to the effective decision-making unit. In fact, some universities between them have some room for improvement, but the traditional DEA magnified CCR model is difficult to reflect. The main defect is that it is impossible to judge whether the effective decision-making unit is really effective and whether there is still the possibility of improvement.

Comparing Tables 1 and 2, when the cross-efficiency model is used, there is no case where the efficiency values of two decision units are simultaneously 1, that is, there are no two decision units that are valid at the same time. The cross-efficiency model can not only overcome the shortcomings of “self-interest” when traditional CCR models choose weights, but also provide a more scientific and reasonable reference for objective evaluation of scientific research performance in universities.

## 4. Conclusion

Based on the DEA method, this study compared DEA cross efficiency evaluation model and traditional CCR model on the basis of reviewing the current research status of scientific research performance evaluation of colleges and universities at home and abroad, and analyzed and evaluated the performance of scientific research input and output of 64 colleges and universities directly under the ministry of education in 2017. Analysis results show that:

Compared with the traditional CCR model, the DEA cross-efficiency evaluation model is a more scientific evaluation method. The empirical research shows that this model effectively avoids the disadvantages of each DMU in the traditional CCR model to adjust the weight according to its own situation to make it beneficial to itself, so that the evaluation results are more objective and comparable. In addition, the cross-efficiency evaluation overcomes the difficulty of judging which optimal problem occurs when several DMUs are effective in the evaluation results of the traditional CCR model. Introducing cross-evaluation mechanism can make up the defect of CCR model of traditional DEA method to some extent.

There is a serious imbalance in the scientific research performance of Chinese universities. Using the DEA cross-efficiency evaluation model and the traditional CCR model, the evaluation results of the scientific research performance of 64 universities directly under the ministry of education in China in 2017 show that there are significant differences in the scientific research performance of different universities, some universities' scientific research performance is relatively low and they fail to make effective use of educational resources.

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