AN EMPIRICAL ANALYSIS OF THE RESEARCH PERFORMANCE EVALUATION OF CHINESE UNIVERSITIES BASED ON THE DEA MODEL

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Abstract: Based on performance evaluation theory and the characteristics of scientific research performance in universities, this study utilizes data from the "Compilation of Scientific and Technological Statistics of Higher Education Institutions" from 2018 to 2022. Following the "input-output-benefit" approach, the DEA-BCC model is employed to analyze the overall research performance of Chinese universities. Human and financial resources are used as input indicators, while academic and social benefits are used as output indicators to construct a research performance evaluation index system for universities. The results indicate that the research performance level of Chinese universities is not high, with pure technical efficiency gradually becoming the leading factor in improving research technical efficiency. Based on these findings, policy recommendations are proposed to enhance the research innovation performance of Chinese universities, focusing on resource allocation, improving evaluation systems, building academic teams, and emphasizing connotative development.

Keywords: DEA Model, Universities, Research Performance Evaluation Study

Introduction

Universities are important bases for cultivating high-level innovative talents and are a driving force in technology transfer and the conversion of research outcomes. The level of scientific research directly affects the development of university disciplines, the quality of faculty, the quality of education, and the ability to serve society. The evaluation of research performance in universities is a crucial part of university research management and plays a vital role in the development of universities. With the continuous enhancement of China's economic strength, the investment in university research funding has also been increasing. It is an urgent and practical issue to explore the input-output performance of university research innovation and how to allocate resources reasonably to improve university research

performance.

Both domestic and international scholars focus on research performance evaluation in universities, primarily revolving around the application of evaluation methods and the construction of indicator systems. The most widely used research performance evaluation methods in academia include Data Envelopment Analysis (DEA), Analytic Hierarchy Process (AHP), and Fuzzy Comprehensive Evaluation (FCE). AHP and FCE are highly subjective, leading to less objective evaluation results. DEA evaluates university research performance from the unique perspective of input-output, gaining significant attention from scholars.

Xu & Li. (2023) established a DEA model and used MATLAB and DEAP 2.1 software to analyze university input-output data, comparing the research efficiency of each university and proposing reasonable policy recommendations. Liu et al. (2019) used DEA to evaluate the performance of research institutions in Heilongjiang universities. Shen et al. (2016) applied the DEA method to study and rank the research input-output performance of local universities in 31 provinces (autonomous regions and municipalities) in China. Rostamzadeh (2021) systematically verified the application of DEA by collecting a list of academic papers published in high-level journals from 2003 to February 2020. Duan. (2021) built an evaluation index system for university research innovation performance based on input-output aspects and used super-efficiency DEA to conduct an empirical analysis of the research innovation performance of Chinese universities in 2015. Zhu et al. (2016) constructed a performance evaluation index system for collaborative innovation to achieve a scientific evaluation of the collaborative actions of innovation subjects from the perspective of collaborative innovation. Wedemeier (2018) used an empirical approach and cross-sectional survey design, employing random sampling to select four private universities in Uganda for empirical analysis of their research innovation performance.

In summary, existing literature has achieved significant success in the choice of evaluation methods and the construction of indicator systems, promoting research performance evaluation in universities to varying degrees. However, it is regrettable that current research often overly focuses on key universities such as the 985 and 211 projects, with relatively few studies evaluating the overall research performance of Chinese universities. Therefore, this paper will take the 31 provinces (autonomous regions, and municipalities) of China as the research object, select appropriate evaluation indicators, and conduct an empirical analysis of the research input-output performance of Chinese universities from 2019 to 2023. Based on this, effective policy recommendations to enhance university research performance will be proposed.

Research Methodology

This paper uses Data Envelopment Analysis (DEA) to evaluate the research performance of

universities in Shandong Province. DEA, developed by American scholar Charnes in 1978, has the advantage of measuring efficiency by comparing the deviation of each decision-making unit from the frontier standard. It does not require weighting or standardizing the data during processing. Chinese universities can be viewed as input-output systems, where, despite differences in scale and level, they can be effectively evaluated based on their inputs and outputs. DEA includes two models: DEA-CCR and DEA-BCC. The CCR model mainly evaluates the relative efficiency among departments, while the BCC model assesses the technical efficiency of production departments. This study uses the DEA-BCC model to analyze the research performance of universities in Shandong Province. The basic expression of the model is as follows:

$$\min \theta_0$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_0 x_{i0}, i = 1,2,\ldots, \ m \\ \sum_{j=1}^{n} \lambda_j x_{ij} \ge y_{ro}, r = 1,2,\ldots, \ q \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda \ge 0, \ j = 1,2,\ldots, \ n \end{cases}$$

In the model, j represents the universities, n represents the total number of universities, x_i（$i = 1,2,\ldots, \ m$）represents the input factors, y_r（$r = 1,2,\ldots, \ q$）represents the output factors, λ_j represents the combination coefficient of the evaluated unit, and θ represents the most efficient value, which ranges between 0 and 1. When θ=1, it indicates that the university's research innovation efficiency is at its maximum; conversely, the closer θ is to 0, the lower the university's research innovation efficiency.

The research spans from 2018 to 2022, selecting 31 provinces (autonomous regions, and municipalities) as the research objects. Considering that research inputs take time to convert into outputs, resulting in a certain lag in research output, the lag period is set to 1 year based on previous studies.

The data required for this research on input-output comes from the "Compilation of Scientific and Technological Statistics of Higher Education Institutions" published by the Ministry of Education's Department of Science and Technology from 2018 to 2022. Given the differences in units of the variables, to reduce errors, the data for the variables were standardized by taking their natural logarithms before calculations. Using higher education institutions in the 31 provinces (autonomous regions, and municipalities) of China as decision-making units, the research calculates the research innovation efficiency values of Chinese universities over the five-year period.

Results

Establishment of the Indicator System

University research activities are complex systems involving multiple inputs and outputs. The evaluation indicator system is crucial for ensuring the purposefulness, representativeness, and authority of the evaluation. Through literature review, it has been found that there is no reliable standard for measuring physical capital input in universities. Scholars generally focus on human and financial aspects when collecting research input indicators.

Based on the research by Zong &Yang (2002), this study selects personnel and internal research funding as input indicators. Drawing from the work of Bhutto, Qin, and others, it selects the number of research projects, scientific books and papers, the number of patent applications, and actual income from patent transfers as output indicators. After comprehensive consideration of the scientific validity and feasibility of the data, the input-output indicator system for university research activities in Shandong Province was established.

The establishment of the research performance evaluation indicator system for universities in Shandong Province mainly focuses on two aspects: input and output. Input Indicators: Human Capital Input: Full-time equivalent research and development personnel. Financial Capital Input: Internal research funding expenditure. Output Indicators: Academic Benefits: Number of scientific books and papers, number of research projects. Social Benefits: Number of patent applications, actual income from patent transfers. The specific indicators are summarized in Table 1.

Table 1: Research Performance Evaluation Indicators for Chinese Universities

Variable properties	Measuring dimensions	Measurement standard
Input indicators	Human capital investment	Research and development full-time equivalent personnel
	Financial capital investment	Internal expenditure on scientific research funds
Output Indicators	Academic Benefit Output	Number of scientific and technological works and papers
		Number of scientific research projects
	Social benefit output	Number of patent applications
		Actual income from patent transfer

Analysis of Research Performance Results of Universities in China

Using the collected panel data, the research input-output data for each year from 31 provinces (autonomous regions, and municipalities) in China were analyzed using DEAP 2.1, an analysis software

developed by Coelli's team. This analysis measured technical efficiency, pure technical efficiency, and scale efficiency.

(1) Technical Efficiency Analysis

Using DEAP 2.1 software, this paper measures the technical efficiency of research performance in universities across various provinces (autonomous regions, and municipalities) in China from 2018 to 2022. As seen in Table 2, the overall technical efficiency of university research performance in China shows an upward trend from 2018 to 2022. The provinces with the highest technical efficiency are Beijing, Jiangsu, Liaoning, Henan, Heilongjiang, Gansu, Qinghai, Sichuan, and Xinjiang. In contrast, provinces with relatively low technical efficiency are mostly located in the eastern regions. Several reasons account for these differences:

In economically developed regions with high educational standards, the overly favorable research environment and excessive research support may lead to inefficient resource allocation and utilization, causing resource waste. This results in lower scale efficiency and decreased research efficiency, thus lowering high-quality research performance.

In economically underdeveloped regions with lower educational standards, the research performance of universities mainly relies on external support.

(2) Pure Technical Efficiency Analysis

From 2018 to 2022, the pure technical efficiency of university research performance in China shows an overall upward trend. Rankings of provinces (autonomous regions, and municipalities) indicate that Beijing, Jiangsu, Liaoning, Henan, Heilongjiang, Gansu, Qinghai, Sichuan, Tibet, and Xinjiang have higher pure technical efficiency, while Fujian, Zhejiang, Anhui, and Jiangxi rank the lowest. The fluctuations are not significant, suggesting that the pure technical efficiency of university research in China is not greatly affected by environmental factors and random disturbances. Research performance across provinces is primarily influenced by scale efficiency, where both overly favorable and inadequate external environments can lead to a decline in scale efficiency.

(3) Scale Efficiency Analysis

Regarding scale efficiency, the scale returns of university research in China from 2018 to 2022 remain constant on average for 12 universities, with an average of 20 universities experiencing decreasing returns to scale. The number of universities with increasing returns to scale is double that of those with decreasing returns. This indicates that the scale of research inputs has reached or is approaching the optimal level, and the allocation of input and output resources in university research needs further improvement.

These analyses highlight the varying efficiency levels among different regions and the factors influencing these disparities. They underscore the need for strategic improvements in resource allocation and utilization to enhance overall research performance in Chinese universities.

Conclusions

Using data from the "Compilation of Scientific and Technological Statistics of Higher Education Institutions" from 2019 to 2023 and following the "input-output-efficiency" approach, this study employs the DEA-BCC model to evaluate the research performance of universities in Shandong Province. The following conclusions are drawn without considering environmental factors and random disturbances, the high-quality output performance of universities shows a phenomenon where "education and economic developed regions have lower performance, while education and economic underdeveloped regions have higher performance.

Although the research efficiency of Chinese universities has improved over the past five years, the progress is slow, and the overall efficiency remains low. Initially, research efficiency and its improvement were mainly supported by scale efficiency. However, since 2020, scale efficiency has started to decline, making pure technical efficiency the primary factor driving improvements in research technical efficiency. This indicates that future improvements in university research efficiency should rely more on intensive development rather than scale expansion.

Recommendations

1) Rational Allocation of Research Resources and Optimization of Resource Allocation. The empirical analysis indicates that there is a "redundancy of input in developed regions and insufficient input in underdeveloped regions" in the research performance of regional universities in China. Therefore, relevant resources should be reasonably allocated to economically underdeveloped and low-education-level regions. This would not only reduce redundancy in advanced regions but also compensate for the insufficient input in underdeveloped regions, allowing them to achieve scale effects. This approach promotes the rational scheduling and optimization of research resources across universities in different provinces (autonomous regions, and municipalities).

2) Strengthen University Research Management and Improve the Research Evaluation System. Universities should enhance their research management levels, establish a correct perspective on research output, and promote the accumulation and incubation of research results. By flexibly employing reward and punishment mechanisms, universities can increase the autonomy and innovation awareness of teaching and research personnel, thereby encouraging independent innovation. Additionally, universities need to develop a scientific research performance evaluation system. They should consider the lag between research input and output, appropriately extending the research assessment period and improving the research assessment mechanism. The research performance evaluation system should utilize objective and scientific evaluation indicators that accurately reflect the research performance of universities, ensuring that these indicators align with the capabilities of the faculty.

3) Provide a Good Academic Environment and Reasonably Structure Research Teams. Universities should provide a conducive academic environment for researchers, fully tapping into their innovative potential and enhancing the capital accumulation levels of innovative talents. Universities should organize structured research activities, accelerate the transformation of research paradigms and organizational models, and cultivate distinctive research centers to effectively strengthen research innovation performance. Educational authorities should grant universities greater autonomy in personnel matters, improving the structure of high-level positions to effectively utilize specialized human capital. Additionally, universities should focus on internal team structure adjustments to minimize unnecessary distractions for researchers, thereby liberating research productivity and providing ample opportunities for their growth and development.

4) Emphasize Intensive Development and Focus on Research Output Quality. Intensive development in university research emphasizes internal deep reforms to stimulate vitality, enhance strength, and improve competitiveness, achieving substantial leapfrog development through qualitative changes driven by quantitative growth. Intensive development should focus on the essential attributes of research, emphasizing the "quality" of research. This means improving the quality and level of research to boost university research performance. Universities should also improve the management system for the transformation of scientific and technological achievements, strengthen organizational leadership and coordination among relevant departments, and enhance communication and cooperation with social enterprises. By providing specialized services for the transformation of scientific achievements for university research teams and researchers, universities can continuously improve the transformation rate of their scientific and technological achievements.

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