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“더블 퍼스트 클래스”를 통한 중국 서부 대학의 연구 효율성에 관한 연구

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Research on Efficiency of Western China’s Universities under the “Double First-Class” Initiative

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요 약 이 연구는 중국 서부지역의 대학을 중심으로 진행되었으며, 2017년부터 2021년까지 12개 대학의 연구수준을 정적 효율성과 동적 효율성을 모두 고려하여 조사하였다. 정적 효율성은 데이터 포락 분석(DEA)을 사용하여 검사하였고, 동적 효율은 Malmquist 모델을 사용하여 분석하였다. 분석결과, 서부12개 대학의 과학연구 효율성은 일반적으로 높지 않았으며 ‘쌍일류’ 건설의 맥락에서 대학의 과학연구 효율성은 증가하는 추세를 보이고 있으며, 과학연구 효율성의 원인으로 최근 몇 년 동안 효율성이 크게 증가하였다. 연구 활동의 TFP (Total Factor Productivity)는 기술진보지수의 영향을 받아 초기에 증가하다가 감소하다가 다시 증가하는 패턴을 보였다. 연구 결론은 서부 대학들의 과학연구 활동을 위해 자원을 합리적으로 배분하여 효과적인 과학연구 메커니즘을 갖추어서, 관리기준을 개선하여야 한다. 이에 과학혁신과 이에 상응하는 성과를 촉진하여, 궁극적으로 중국 서부의 과학기술 수준을 높일 수 있어야 하겠다.

주제어 더블퍼스트클래스, 중국서부지역, DEA-Malmquist 모델, 과학활동, 효율성

Abstract The research focuses on the provincial universities in the western region of China and investigates the research level of 12 provincial universities from 2017 to 2021, considering both static efficiency and dynamic efficiency. The static efficiency is examined using Data Envelopment Analysis (DEA), while the dynamic efficiency is analyzed using the Malmquist model. The analysis results are as follows: the scientific research efficiency of universities in the 12 western provinces is generally not high. Against the background of the “Double First-Class” construction, the overall efficiency of scientific research in universities is showing an increasing trend. The main reason for the increase in scientific research efficiency is the increase in scale efficiency in recent years. The total factor productivity (TFP) of research activities is influenced by the technology progress index and exhibits a pattern of initial increase, followed by a decline, and then an increase again. Research conclusion: Western colleges and universities should reasonably allocate resources for scientific research activities, perfect scientific research mechanisms, improve management standards, promote scientific innovation and corresponding achievements, and ultimately raise the scientific and technological level in western China.

Key Words Double first-class, China’s western Areas, DEA-Malmquist model, Research efficiency, Efficiency

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1. Introduction

In February 2022, the Ministry of Education, the Ministry of Finance, and the National Development and Reform Commission announced the list of the second batch of "Double First-Class" and universities. One of the goals is to improve the research and development capability of universities, enhance the creativity resources and build a socialist modernization in an all-around way. Powerful countries provide strong support [1]. In accordance with the figures from the National Bureau of Statistics, from 2017 to 2021, R&D activities funds and personnel of China's universities continued to grow. In 2021, the funding of universities was 218.05 billion yuan, an growth of 15.8%, 1.408 million R&D personnel, an growth of 10.5%. With the continuous growth of national R&D investment, China is getting rid of the role of technological innovation tracker and is steadily moving towards an independent innovation country. Referring to the 2022 Global Innovation Index (GII) released by the World Intellectual Property Organization (WIPO) in 2022 shows that China's scientific and technological innovation capacity ranks 11th among 132 economies, rising one more place than the previous year, and has been growing for 10 consecutive years.

As one of the three executing entities of scientific and technological innovation, universities play an important role in national scientific and technological innovation, and their scientific research level has gradually become an important indicator of national or regional scientific and technological levels. Making full use of university platforms and rationally allocating scientific research resources is an effective way to enhance areas innovation capabilities and an important way to promote capabilities. In the western region, where the economy is relatively backward, how to reasonably allocate limited scientific research resources, improve scientific research efficiency, improve self-development ability, and promote sound and rapid development of the local economy has always been a major strategic task facing the country. To this end, this study focuses on the regional universities in western China, taking into account the background of the innovation-driven development strategy under the "Double First-Class" initiative, and using the DEA model and Malmquist index to study the scientific research efficiency of universities in the western region during the construction period of "Double First-Class". The significance of this study lies in systematically sorting out the level of scientific and technological investment and output of universities in the western region under the background of the "Double First-Class" construction. It provides an effective way to optimize the allocation of scientific research resources in universities, improve scientific research efficiency, and provide a certain theoretical reference for the formulation of scientific and technological innovation policies in the western region in the next stage.

2. Related Concepts and Literature Review

2.1 Related concepts

2.1.1 Double first-class

First-class universities and disciplines of the world, referred to as "double first-class", is a major strategic decision made by the Central Committee of the Communist Party of China and the State Council. It is also another national strategy in China's higher education field after "Project 211" and "Project 985", which is conducive to improving China's comprehensive strength and international competitiveness of higher education, It will provide strong support for the realization of the "Two Centenaries Goals" and the Chinese Dream of the great rejuvenation of the Chinese nation [2].

2.1.2 Western Areas

The western areas of China are the economic and geographical division of China, including Chongqing, Sichuan, Shanxi, Yunnan Province, Guizhou, Guangxi, Gansu, Qinghai, Ningxia, Xizang, Xinjiang, and Neimenggu, involving 12 provinces,autonomous regions, and municipalities directly under the Central Government. The land area is 6,781,589 square kilometers, accounting for 70.6% of the total area of the country; the population is 379,558.7 million, accounting for 27.2% of the total population of the country. The vast majority of the western region is characterized by economic underdevelopment, necessitating intensified development efforts [3].

2.1.3 Scientific research efficiency

We regard scientific research activities as a production activity with multiple inputs of production factors and multiple output factors. We can understand scientific research efficiency as the maximum scientific research output under the premise of a certain total input of scientific research production factors; or under the premise of a certain total amount of scientific research output factors, as the minimum input level of scientific research production factors [4]. The level of research efficiency can be used as an evaluation reference for whether the organization allocates resources reasonably and uses technology reasonably.

2.2 Mediation effect of bank supervision

The "Double First-Class Initiative" is an intricate and holistic endeavor that encompasses the reform of scientific research in Chinese universities. In the last few years, The concern regarding the efficiency of scientific research in universities has been widely concerned and deeply studied by scholars. Sha Jushan [5] applied DEA and Malmquist index to assess the scientific research efficiency of universities and investigate the factors that contribute to it. Luo Hang [6] used the DEA method to analyze the "985 Project" of Chinese science and technology and provided ideas and offer recommendations and ideas for enhancing efficiency and optimizing the allocation of educational resources in engineering and technology-focused universities. Wang Hengxin et al. [7] Exploring the dynamic research efficiency of universities using the group decision-making DEA method. Lin Tao, Lu Han [8] conducted a systematic evaluation of the science and technology input-output of 13 high-level universities in Guangdong Province to provide theoretical and practical support for the formulation of relevant policies in the next stage. Luo Xi, Gao Rongrong, Cao Lina [9] used the DEA-Malmquist index evaluation model to measure and analyze the transformation efficiency of scientific and technological achievements in 32 universities in Jiangsu Province. Na Chao [10] used DEA to analyze the utilization efficiency of science and technology budgets in various provinces in China from 2013 to 2017, and proposed directions for improvement. Li Yanhua, Zhang Yueting [11] took China's "Double First-Class" universities as research objects, used DEA and Malmquist model to measure the scientific research efficiency from 2014 to 2017, and found that the scientific research efficiency of the selected universities was high, but there were differences. At the same time, the results show that with the change of technological progress index, the total factor productivity presents a trend of first increasing and then decreasing. Zong Xiaohua, Fu Chengxiang [12] selected "Double First-Class" universities directly under the Ministry of Education to build an index system highlighting the quality and contribution of scientific research, and analyzed the efficiency of scientific research in universities and its changes by using ultra-efficient BCC model and Malmquist model. The study reveals that universities, on the whole, exhibit a low level of research efficiency, but only slowly. The major factors driving the increase in research efficiency are the improvements in research management efficiency and the growth in scale efficiency, while the

scale effect tends to fade away. Lu Lianju [13] used the DEA method to evaluate the research efficiency of the "Double First-Class" universities in the central region before being selected. The results showed that the efficiency level of scientific research input and output before the selection of universities was not high.

By reviewing and comprehending the existing literature, it is found that research on scientific research efficiency under the "Double First-Class" initiative in China has mainly focused on directly affiliated universities of the Ministry of Education and local universities, particularly research-oriented universities. Additionally, the research data available are generally from before 2017. There is a dearth of studies on the research efficiency of regional universities. Therefore, this paper aims to examine the research efficiency of western region universities from 2017 to 2021 within the framework of the "Double First-Class Initiative" to address the existing research gap in this particular area.

3. Research Methods

3.1 DEA model

Charnes and Cooper (1978) and other scholars put forward the Model-free evaluation method DEA on the basis of relative efficiency evaluation research, which is used to analyze and evaluate Productivity in multi-input, multi-output configurations [14]. The principle of data envelopment analysis is to evaluate the relative validity of the homogeneous decision-making unit (DMU) by using the linear programming method according to the multi-input index and multi-output index. Its advantage is that it can measure the efficiency between multiple pairs of input and output without knowing the functional relationship between input and output. Judging whether DEA is effective according to each DMU is essentially judging whether it is at the "production frontier" of the production set [15]. The DEA model is divided into the CCR model with constant returns to scale and the BCC model with variable returns to scale based on the characteristics of returns to scale. The CCR model measures the technical efficiency when returns to scale are not considered, and the BCC model breaks down total technical efficiency (TE) into pure technical efficiency (PTE) and scale efficiency (SE) with its value between 0 and 1, and TE = PTE × SE.

3.2 Malmquist index

Malmquist index was proposed by Swedish economist Malmquist in 1953 [16]. The implementation of this method bridges the gap in traditional DEA models, enabling dynamic assessment of efficiency. The formula is as follows:

$$TFP = TEch \times TECHch = PTEch \times SEch \times TECHch$$

(1) TFP refers to Total Factor Productivity. TFP > 1 indicates an increasing trend. TEch represents the dynamic change in technical efficiency from time t to t+1. When TEch > 1, it signifies an improvement in technical efficiency; otherwise, the opposite is true. TECHch represents the trend of efficiency change due to the technological progress index from time t to t+1. When TECHch > 1, it indicates technological progress and an improvement in efficiency; Conversely, the conclusion is the reverse. TEch is dissected into scale efficiency (SEch) and pure technical efficiency (PTEch). In this study, each province in western China serves as a DMU, and the Malmquist index analysis is employed to calculate the change in TFP [17].

3.3 Index selection

Golany and Roll (1989) concluded through model analysis that the quantity of DMUs participating in the evaluation should be at least twice the sum of the number of input and output items [18]. Through reviewing the previous research literature, it is found that

there are indicators such as R&D personnel, teaching and research personnel, research funds, research and development funds, the number of published papers, the number of published scientific and technological works, the number of patent applications, and the number of patent grants. The number of DMUs studied in this paper is 12 provinces (cities, autonomous areas) in the west, and the input and output indicators need to be as simple as possible. Therefore, the two indicators of the full-time equivalent of R&D personnel and scientific and technological funds in universities are used as the input of human and financial resources; the number of published papers, published books and scientific and technological projects in the scientific and technological achievements of universities is used as indicators to measure the output of scientific research in universities. The input-output indicators are shown in Table 1:

Table 1 Input-output indicators

	Indicator name	unit
Input indicators	Full-time equivalent of R & D personnel in universities	person/year
	R & D Expenditure	thousand yuan
output indicators	published papers	articles
	published works	department
	Science and Technology Topics	item

3.4 Data collection

Within the scope of this paper, 12 provinces (municipalities and autonomous regions) including Sichuan, Chongqing, Shanxi, Yunnan, Guizhou, Guangxi, Gansu, Qinghai, Ningxia, Xizang, Xinjiang and Inner Neimenggu are taken as the research objects, and the data come from "China Education Statistical Yearbook" and so on.

4. Empirical Analysis

4.1 Static efficiency analysis

Using DEAP software to process the collected data, the scientific research efficiency of universities in the western areas can be obtained. The specific analysis is as follows:

As shown in Table 2, the average comprehensive TE of research and development in universities in the western areas is 0.8366, indicating that the overall input-output is relatively high. From 2017 to 2021, the average scientific research efficiency of universities showed an increasing trend in the first 4 years, and fluctuated a bit in the fifth year, indicating that the general research efficiency in the western areas is good under the "double first-class" construction policy. From the perspective of each year, in 2017-2018, the

Table 2 Comprehensive technical efficiency of scientific research from 2017 to 2021 (TE)

DMU	2017	2018	2019	2020	2021	mean	Ranking
Chongqing	0.732	0.717	0.762	0.922	0.915	0.8096	7
Sichuan	0.727	0.671	0.67	0.79	0.805	0.7326	10
Guizhou	0.791	0.886	0.905	1	1	0.9164	4
Yunnan	0.719	0.684	0.683	0.75	0.702	0.7076	11
Xizang	0.74	0.686	0.661	1	0.785	0.7744	9
Shanxi	1	1	1	0.852	0.991	0.9686	2
Gansu	0.928	0.925	1	1	0.655	0.9016	5
Qinghai	0.729	0.705	1	1	1	0.8868	6
Ningxia	0.562	0.681	0.98	0.824	0.944	0.7982	8
Xinjiang	0.73	0.925	1	1	1	0.931 0	3
Guangxi	0.477	0.607	0.482	0.635	0.858	0.6118	12
Neimenggu	1	1	1	1	1	1	1
Mean	0.761	0.791	0.845	0.898	0.888	0.8366	

areas with effective scientific research efficiency in universities are Shanxi and Inner Neimenggu; in 2019, they are Shanxi, Gansu, Qinghai, Xinjiang and Inner Neimenggu; in 2020, they are Guizhou, Xizang, Gansu, Qinghai, Xinjiang and Inner Neimenggu; in 2021 they are Guizhou, Qinghai, Xinjiang and Inner Neimenggu. From 2017 to 2021, only Inner Neimenggu has effective scientific research efficiency. Among them, Chongqing, Sichuan, Yunnan, Xizang, Ningxia and Guangxi are all lower than the regional average comprehensive efficiency, reflecting that scientific research efficiency is not ideal and the level of scientific research is not high.

As shown in Table 3, during the first batch of "Double First-Class" initiative, the average PTE in the western region was 0.941, close to the effective state. The overall trend of PTE average growth from 2017 to 2021 indicates that the level of scientific research and technology in universities is steadily improving. The results indicate that PTE was effective in four regions: Sichuan, Xizang, Shanxi, and Inner Neimenggu from

Table 3 Pure technical efficiency of scientific research from 2017 to 2021(PTE)

DMU	2017	2018	2019	2020	2021	Mean	Ranking
Chongqing	0.914	0.963	1	1	1	0.9754	5
Sichuan	1	1	1	1	1	1	1
Guizhou	0.792	0.891	0.911	1	1	0.9188	10
Yunnan	0.916	0.969	0.879	0.873	0.989	0.9252	9
Xizang	1	1	1	1	1	1	1
Shanxi	1	1	1	1	1	1	1
Gansu	0.931	0.931	1	1	0.86	0.9444	7
Qinghai	0.824	0.84	1	1	1	0.9328	8
Ningxia	0.572	0.709	1	0.827	0.983	0.8182	12
Xinjiang	0.819	0.928	1	1	1	0.9494	6
Guangxi	1	0.669	0.484	1	1	0.8306	11
Neimenggu	1	1	1	1	1	1	1
Mean	0.897	0.908	0.939	0.975	0.986	0.941	

Table 4 Scale Efficiency of scientific research from 2017 to 2021 (SE)

DMU	2017	2018	2019	2020	2021	Mean	Ranking
Chongqing	0.801	0.745	0.762	0.922	0.915	0.829	8
Sichuan	0.727	0.671	0.67	0.79	0.805	0.7326	12
Guizhou	0.999	0.994	0.994	1	1	0.9974	2
Yunnan	0.785	0.706	0.776	0.859	0.71	0.7672	11
Xizang	0.74	0.686	0.661	1	0.785	0.7744	10
Shanxi	1	1	1	0.852	0.991	0.9686	5
Gansu	0.997	0.994	1	1	0.761	0.9504	6
Qinghai	0.884	0.84	1	1	1	0.9448	7
Ningxia	0.984	0.961	0.98	0.996	0.961	0.9764	4
Xinjiang	0.892	0.997	1	1	1	0.9778	3
Guangxi	0.477	0.908	0.997	0.635	0.858	0.775	9
Neimenggu	1	1	1	1	1	1	1
Mean	0.857	0.875	0.903	0.921	0.899	0.891	

2017 to 2021; Guizhou, Yunnan, Qinghai, Ningxia, and Guangxi are lower than the average PTE in the western region, indicating that these provinces should strive to improve their scientific research management mechanisms and enhance their scientific research level.

As shown in Table 4, the overall average of SE in the western region is 0.891. From 2017 to 2021, the average of SE showed a trend of first increasing and then decreasing, indicating that universities in the western region need to increase their research investment.

As shown in Figure 1, from 2017 to 2021, the comprehensive TE changing trend of the 12 provinces in the western areas mainly changes with the SE. The PTE is lower than 1 in seven provinces (cities, autonomous areas) except Sichuan, Xizang, Shanxi and Inner Neimenggu, reflecting that these provinces should improve the scientific research management system and operation mechanism, and at the same time increase investment in scientific research to improve Contribution rate of scientific and the technological progress. The scale efficiency (TE) is lower than 1 in provinces except Guizhou and Inner Neimenggu. It can be concluded that these areas should first improve the efficiency of research resource allocation in universities, increase funding and personnel input, and improve economies of scale.

Figure 1 Average dynamic chart of THE, TE and SE of university scientific research in western China from 2017 to 2021

Only inner Neimenggu SE is valid; Guizhou, Shanxi, Gansu, Qinghai, Ningxia, and Xinjiang are more than 0.9, close to effective; Chongqing, Sichuan, Yunnan, Xizang, and Guangxi are below average; Guangxi has the lowest SE, with an average of 0.775.

4.2 Dynamic efficiency analysis

The research in question employed the Malmquist index technique to carry out a dynamic analysis of research efficiency in the western region of China. As shown in Table 5, the average change and decomposition of TFP in the western region of China from 2017 to 2021 are presented. From 2017 to 2021, the average total factor productivity in the western areas is 0.932, with an annual average decrease of 6.8%; the average technical efficiency is 1.017, with annualized growth rate 1.7%; the average technological progress index is 0.917, with an average annual decline the rate is 8.3%. The decrease in total factor productivity is due to the technological progress index. The province with the highest total factor productivity is Qinghai, compounded annual growth rate of 4.6%; the total factor productivity of the remaining 11 provinces (cities, autonomous areas) is lower than 1. Among them, the technological progress index of Chongqing, Sichuan, Guizhou, Qinghai, Ningxia, Xinjiang, Guangxi and Inner Neimenggu was lower than 1, resulting in a decline in total factor productivity; the technological efficiency and technological progress index of Yunnan, Xian, Shanxi and Gansu provinces were both less than 1, and both are factors that lead to low total factor productivity. The results show that the growth of technical efficiency mainly comes from the improvement of resource allocation, management level and size advantages of research study in college under the "double first-class" construction. The drop in the technology progress index is indicative of the limited progress in enhancing research quality and research capacity in universities located in the western region, resulting in

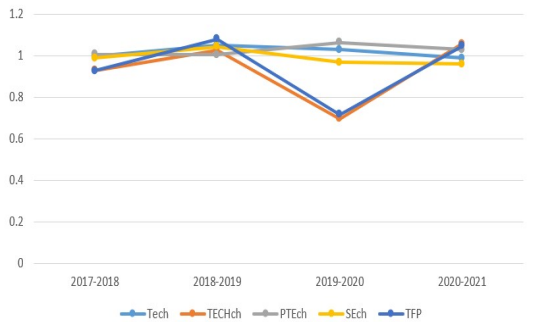
Table 5 Average change and decomposition of total factor productivity in western China from 2017 to 2021 (TFP)

DMU	Tech	TECHch	PTEch	SEch	TFP	FTP Ranking
Chongqing	1	0.935	1	1	0.935	6
Sichuan	1.05	0.924	1	1.05	0.97	5
Guizhou	1.011	0.918	1.06	0.953	0.927	7
Yunnan	0.961	0.899	1.019	0.943	0.863	11
Xizang	0.984	0.93	1	0.984	0.915	8
Shanxi	0.98	0.912	1	0.98	0.893	9
Gansu	0.916	0.915	0.98	0.934	0.838	12
Qinghai	1.082	0.967	1.049	1.031	1.046	1
Ningxia	1.076	0.914	1.105	0.974	0.983	3
Xinjiang	1.068	0.917	1.051	1.016	0.979	4
Guangxi	1.088	0.907	1.061	1.025	0.987	2
Neimenggu	1	0.871	1	1	0.871	10
Mean	1.017	0.917	1.027	0.99	0.932	

a slow pace of expansion in the forefront of research efficiency.

As shown in Figure 2, the TFP annual average exhibits significant fluctuations, showing a trend of initial increase, followed by a decrease, and then another increase. The trend of TFP changes primarily follows the fluctuations in the technology progress index. The fluctuations in TFP values indicate that research activities in Western region universities are quite active, but there is also instability in research production.

Figure 2 TFP mean value and its decomposition form 2017 to 2021



5. Conclusions

In this particular study, the research efficiency of universities in 12 provinces (municipalities, autonomous regions) in western China was evaluated using the DEA and Malmquist index methods. The empirical results are analyzed as follows: (1) The static analysis results of the DEA model show that The DEA valid province is Inner Neimenggu, and the remaining 11 provinces are not DEA valid. The overall scientific research efficiency has increased, which proves that under the "Double First-Class" initiative, the scientific research efficiency of universities in the western areas has been improved. Scientific research efficiency is mainly affected by scale efficiency, followed by pure technical efficiency, indicating that the western areas should first optimize the allocation of scientific research resources, increase investment, and at the same time improve the scientific research mechanism and management level. (2) By utilizing the Malmquist index analysis, the study demonstrates that the inter-provincial universities' total factor productivity in scientific research is linked to changes in the technology progress index. It can be seen that the inter-provincial universities in the west can maintain the overall level

of research study efficiency, can enhance the quality and ability of research study while maintaining scientific research investment.

The limitation of this study is that the input-output indicators are insufficient, and the second is that only western provinces are used to evaluate efficiency. Future research will expand the scope to most provinces in my country, and at the same time expand input-output indicators to conduct in-depth research and analysis of the scientific research status of Chinese universities.

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