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Research on the School-running Efficiency of Ordinary Universities in the Western Region Based on the Combined Model

Yan Zhao*

School of Management, Xi'an Polytechnic University, Xi'an, 710600, China

Corresponding author: Yan Zhao, 15517121107@163.com

Abstract: Efficiency is one of the core elements in the "outcome evaluation" within the educational evaluation in the new era. To investigate the differences and dynamic evolution of the efficiency level of ordinary universities in various provinces of western China, this study uses the PCA-DEA combination model from the perspective of input-output to measure the efficiency of universities in various provinces of western China from 2012 to 2021.Research shows that the overall efficiency of ordinary universities in the western region is in a non-effective state, with 70.8% of decision-making units achieving pure technical efficiency effectiveness, and the vast majority of decision-making units in a state of constant or increasing returns to scale. The overall efficiency of universities in the western region fluctuates relatively greatly, with a positive trend. However, there are significant differences in total factor productivity changes between different provinces. Finally, based on the research conclusions, corresponding countermeasures and suggestions are proposed.

Keywords: Regular Universities; School Efficiency; PCA-DEA Combination Model

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1.Introduction

The "Modernization of Education in China 2035" explicitly proposes to build a higher education system with Chinese characteristics and world-class standards, emphasizing the use of performance as a lever to construct an evaluation system with Chinese characteristics. As China's higher education enters the stage of comprehensive popularization, the scale of higher education continues to expand, and the improvement of the effi ciency of higher education has become an objective requirement for the high-quality development of higher education in the new era. Due to the unique geographical location and economic development of universities in the western region, it is a long and arduous task to improve their operational effi - ciency. The study adopts DEA-BCC model and Malmquist index model to investigate the effi ciency of ordinary universities in the western region from 2012 to 2021, aiming to understand how the effi ciency of universities in the western region has improved in recent years? In order to strengthen the understanding of the current effi ciency of higher education in the western region, and to propose countermeasures and suggestions for improving the effi ciency of higher education, in order to promote the high-quality development of higher education in the western region.

2.Literature Review

As a type of outcome evaluation, the efficiency evaluation of higher education refers to the ratio of various resources invested

in the university to the direct output results, mainly pursuing the goal of "obtaining the maximum output from a given amount of input"[1]. The academic research on the efficiency of higher education has achieved fruitful results, presenting a multidimensional focus.

From the perspective of research objects, domestic research on the evaluation of the efficiency of higher education can be divided into three levels in China: one is to study the external resource allocation efficiency of the education system (external efficiency) and the internal input-output efficiency of the education system (internal efficiency). External efficiency is measured by studying the contribution of education to economic growth, social development, and educational benefits, while internal efficiency is measured by studying the production efficiency, allocation efficiency, utilization efficiency, and X-efficiency of educational inputs[2]. The second is to divide the research sample into different levels of research. From a macro perspective, it refers to the ratio of a country's total investment in higher education to the total economic and social development benefits it brings; From a meso level perspective, it refers to the ratio of input to output in higher education in a certain region or individual administrative area. At the micro level, it refers to the input-output ratio or productivity of a certain link in the process of running a certain type or a certain university. The third is to focus on subdividing the internal efficiency of higher education, such as the teaching efficiency and research efficiency of universities, and strive to accurately perceive the operational effectiveness of different functional sectors.

From the perspective of research methods, common methods for evaluating higher education efficiency include parametric methods represented by stochastic frontier analysis (SFA) and non-parametric methods represented by data envelopment analysis (DEA). The DEA method is suitable for handling situations with multiple inputs and outputs, and does not require strict functional assumptions, let alone considering the dimensions of input-output indicators. Therefore, it has a wide range of applications in the field of education. For example, Yuan Wei[3] ,Zhong Jianhua[4], Rong Yaohua[5], You Li[6], Pan Dan[7]and others used DEA models to evaluate the efficiency of ordinary universities in China.

In summary, although scholars have conducted in-depth research on the efficiency of higher education institutions, there is currently a lack of research on the overall efficiency of higher education institutions, as well as the differences and dynamic evolution characteristics of efficiency in different provinces. Especially, research on the efficiency of higher education institutions in the western region is rare. Based on this, this study takes western universities as the research object and uses DEA-BCC model and Malmquist index model for static and dynamic analysis, respectively.

3.Research Design and Research Methods

3.1 Indicator selection

The core of measuring the efficiency of ordinary universities is to select appropriate evaluation indicators. From the perspective of input-output, investment in universities is generally divided into human resources investment, material resources investment, and financial resources investment. In terms of output, there are three basic outputs: general talent cultivation, scientific research, and social services. Referring to the indicator system designed by Pan Dan[7],Song Zhiyan[8], Zhang Qiang[9], Zhang Xingsheng[10]115-116 and others, the input-output indicators selected in this study are shown in Table 1.

Table 1 evaluation index system of university running efficiency

Primary indicators	Secondary indicators	Tertiary indicators	units	symbol
Input index	Human input	student-teacher ratio	%	i1
		proportion of full-time teachers with graduate degree	%	i2
		full time equivalent of research and development personnel	person-year	i3
	Material input	Total floor area	10000sq.m.	i4
		value of teaching and scientific research instruments and equipment	10000rmb	i5
		book stock	ten thousand volumes	i6
	Financial input	total investment in Education	trillion yuan	i7
		R&D expenditure	trillion yuan	i8

Primary indicators	Secondary indicators	Tertiary indicators	units	symbol
Output index	Talent training	number of students in school	ten thousand people	o1
		number of graduates		o2
		number of degrees awarded		o3
	Scientific research	number of R&D projects	term	o4
		number of published scientific papers	piece	o5
		number of published scientific and technological works	type	o6
		number of patent applications	piece	o7
	Social services	actual income in the year of patent sale	10000rmb	o8
		number of R&D achievements application and science and technology service projects	term	o9
		actual income of technology transfer contract in the current year	10000rmb	o10

3.2 Data sources

This paper evaluates the efficiency of colleges and universities in 12 provinces in the western region. The input-output data of colleges and universities in each province are from the statistical data released by the state from 2012 to 2022. Specifically, in the input-output index data selected by the Research Institute, i1, i2, i4, i5, i6, o1, o2, o3 are from the China Education Statistics Yearbook, i3, i8, o4, o5, o6, o7 are from the China Science and Technology Statistics Yearbook, and colleges and universities include full-time colleges and their affiliated hospitals. i7 is from the statistical yearbook of China's education funds, and o8, o9 and o10 are from the compilation of scientific and Technological Statistics of colleges and universities.

3.3 Research methods

3.3.1 Principal component analysis (PCA)

The principal component analysis method is based on the principle of difference. It realizes data dimensionality reduction without affecting the representative indicators. By analyzing several initial variables, it recombines them into new simplified principal component variables and forms a principal component matrix[11]. There are many input-output indicators for running colleges and universities constructed in this paper. If DEA analysis is carried out directly, the results may be inaccurate due to the multicollinearity between the indicators. And in data envelopment analysis, the number of input and output indicators should maintain a certain balance, and the number of samples should be 2-3 times or more than the number of input and output indicators. Therefore, before DEA analysis, the principal components of input-output indicators are extracted, and the dimensionality reduction idea is used to convert many indicators into several components, so as to make the research results accurate.

3.3.2 Data envelopment analysis (DEA)

(1) BCC model

BCC model evaluates the relative efficiency of DMU under variable return to scale (VRS). The calculated efficiency value is the comprehensive technical efficiency (TE), which can be decomposed into pure technical efficiency (PTE) and scale efficiency (SE). In practical application, the efficiency value decomposition of BCC model can help decision makers to analyze the root cause of inefficiency. If TE=1, then PTE=1 and se=1, it means that there is neither waste of technology nor mismatch of scale in the decision-making unit. If TE<1, it can be further analyzed: if PTE<1 and se=1, it means technical inefficiency. The decision-making unit may have management or technical problems in the production process, and it needs to improve the efficiency by improving the technical ability and management process. If PTE=1 and SE<1: it means that the size of the decision-making unit may be improperly configured, and the efficiency needs to be improved by adjusting the production scale.

(2) Malmquist index model

The traditional CCR and BCC models are only applicable to cross-sectional data, that is, they can only compare the production efficiency of decision-making units at the same time. DEA Malmquist index model can measure the dynamic change of the efficiency of decision-making units in different periods, and can be used to analyze panel data, which has a wide range of applications. The total factor productivity change index (TFP) can be divided into technical efficiency change index (EC) and technical progress index (TC). EC is the change of technical efficiency from stage T to stage T+1. If EC is greater than 1, it means that the technical efficiency has been improved and the gap between DMU and the production frontier has been narrowed. TC is the level of technological progress from stage T to stage T+1. If TC is greater than 1, it means that the production possibility boundary expands outward and technological progress. Compare the TFP value with 1 to judge the change of TFP. When TFP ＞ 1, it means that the total factor production efficiency has been improved and the production efficiency has been improved. The extent of improvement depends on the proportion of more than 1; When TFP=1, it means that the total factor productivity remains unchanged; When TFP ＜ 1, it means that the total factor production efficiency decreases and the production efficiency deteriorates.

4.Empirical analysis results

4.1 Results of PCA

This paper uses SPSS statistical software to standardize the collected index data, and tests the correlation of input-output indicators of colleges and universities in 12 provinces in the western region. It is found that the correlation coefficients of input and output indicators are positive, and the absolute values of most correlation coefficients are greater than 0.3, and some coefficients are 0.8 or more, indicating that the correlation between input and output is large. According to the principle of cumulative variance contribution rate ≥ 85%, three principal component scores of input and three principal component scores of output can be obtained respectively. Due to the non-positive data of the index volume after dimension reduction, the data conversion is carried out in this study. The conversion formula is: A'=（A-min A）/(max A-min A) + 1，Where A' is the new variable, A is the original variable, and the value range of the new variable after conversion is [1, 2]. The above transformation does not affect the essential meaning of the variable. The statistical description of the new input-output indicators after data processing is shown in Table 2.

Table 2 statistical description of index data

	index	samples	min	max	mean	sd
University Investment	IN1	120	1	2	1.468	0.208
	IN2	120	1	2	1.340	0.247
	IN3	120	1	2	1.221	0.218
University Output	OUT1	120	1	2	1.302	0.246
	OUT2	120	1	2	1.265	0.254
	OUT3	120	1	2	1.112	0.198

Note: it is obtained from SPSS operation results.

4.2 Results of DEA

On the basis of constructing the evaluation index system of university running efficiency mentioned above, this paper uses Dearun tool to measure the university running efficiency of 12 provinces (cities, districts) in the western region from 2012 to 2021, and obtains the following two results.

4.2.1 Static analysis based on DEA-BCC model

(1) Comprehensive efficiency. In the past ten years, the average comprehensive efficiency of universities in Western China has been higher than 0.9 for seven years, and the average comprehensive efficiency in 2016, 2017 and 2021 is lower than 0.9, indicating that there have been major problems in the overall efficiency of universities in Western China in the past three years. At the same time, almost half of the provinces show the problem of school running resource allocation every year, that is, about half of the provinces' school running efficiency is not effective. However, some provinces can reasonably use various

school running resources to achieve more optimized school running output on the basis of achieving efficiency. For example, the comprehensive efficiency value of Shaanxi Province from 2012 to 2021 is 1, which is higher than the average level of the western region, indicating that Shaanxi Province is the benchmark Province in the western region. The input factors not only reach the optimal production scale under the effectiveness, but also achieve the production efficiency of the optimal scale due to the improvement of the local government's decision-making and management level, which is worth learning and reference from other provinces and cities.

Table 3 comprehensive efficiency of colleges and universities in Western Regions

tech	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DMU1	0.984	0.980	0.969	0.977	0.954	0.961	0.987	1.000	0.992	0.985
DMU2	1.000	1.000	1.000	0.998	0.995	0.974	0.997	1.000	1.000	1.000
DMU3	1.000	1.000	1.000	1.000	0.979	0.994	1.000	1.000	1.000	1.000
DMU4	1.000	1.000	1.000	1.000	1.000	0.997	1.000	1.000	1.000	1.000
DMU5	0.999	0.978	0.985	0.973	0.957	0.948	0.976	0.977	0.989	0.988
DMU6	0.994	0.993	0.996	1.000	0.991	1.000	1.000	1.000	1.000	1.000
DMU7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.971
DMU8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
DMU9	1.000	1.000	1.000	1.000	0.971	0.984	1.000	0.997	0.989	0.984
DMU10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.996	0.958
DMU11	0.996	0.995	0.996	0.989	0.980	0.975	0.987	0.982	0.978	0.961
DMU12	0.987	0.980	0.984	0.960	0.950	0.941	0.966	0.983	0.954	0.969
mean	0.997	0.994	0.994	0.991	0.982	0.981	0.993	0.995	0.992	0.985

Note: according to the results of DEA software, the specific names of 12 provinces are hidden here, and DMUi is used instead, where I=1, 2, 3,…12.

(2) Pure technical efficiency. The average value of the overall pure technical efficiency in the western region is 0.997, which is in the non-effective range, that is, there is a problem of inefficient utilization of resources in running colleges and universities, there is still room for improvement in resource allocation management, and resource utilization efficiency needs to be further optimized. There are 85 decision-making units with a pure technical efficiency value of 1 in the western region. Among them, Sichuan, Tibet, Shaanxi, Gansu and Qinghai have achieved pure technical efficiency from 2012 to 2021, achieving the maximum output effect in running colleges and universities, and making effective use of resources; The pure technical efficiency value of 35 decision-making units is less than 1, which does not reach the pure technical effective state. The lowest pure technical efficiency of Guizhou in 2017 is 0.953, indicating that the input factors are not fully utilized, and the waste of resources reaches 4.7%; There are 24 decision-making units that achieve weak DEA efficiency. For example, the comprehensive efficiency of Inner Mongolia in 2016 was 0.954, and the pure technical efficiency was 1. Through the input-output redundancy analysis, it can be seen that the decision-making unit can not reduce the input or increase the output in equal proportion, but the human and material inputs may be reduced.

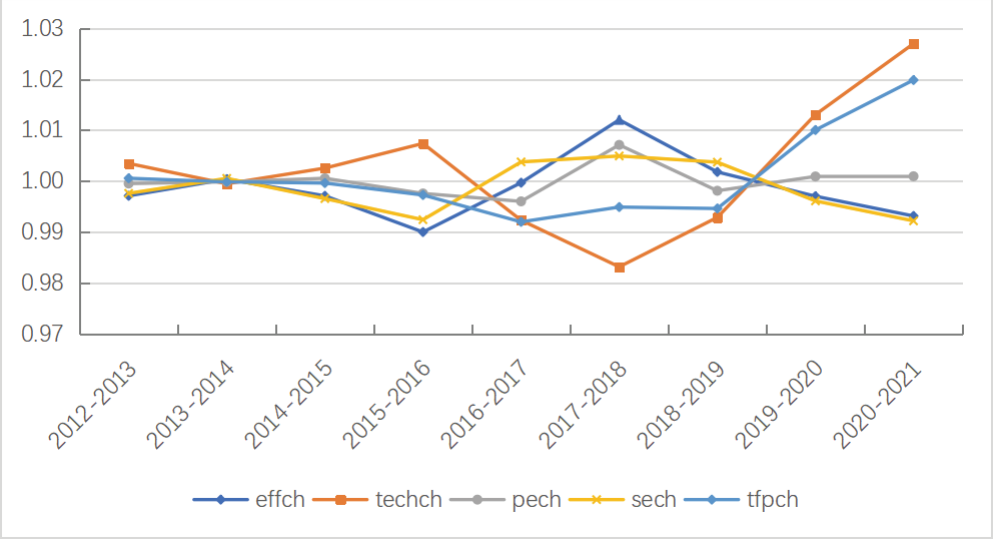
(3) Scale efficiency. From 2012 to 2021, there were 63 decision-making units with the same return to scale, accounting for the highest proportion. The decision-making units with the same return to scale can steadily maintain the synchronous growth of output when expanding input, and can expand or remain unchanged; There are 54 decision-making units in the state of increasing returns to scale, which shows that they have the potential to achieve a higher proportion of output growth by expanding investment. In the process of running a university, it is necessary to increase investment and expand scale to achieve the optimal state of scale; There are three decision-making units with diminishing returns to scale, indicating that there are few decision-making units that need to be scaled down in the western region. This can also reflect that there is room to expand the scale of colleges and universities in the western region, and it is necessary to further increase the investment in

Colleges and universities in the western region.

4.2.2 Dynamic analysis based on DEA Malmquist index model

(1) The time trend characteristics of Malmquist index. During 2012-2021, the average value of the total factor productivity change index, technological progress index and pure technical efficiency change index in the western region were greater than 1, indicating that the overall trend of the total factor productivity of colleges and universities in the western region was positive. From the perspective of stage change, the total factor productivity change index from 2013 to 2019 is less than 1, indicating that the total factor productivity level of the university running efficiency in the western region has declined compared with the previous period, and the efficiency has decreased significantly. From 2019 to 2021, the total factor productivity change index is greater than 1, which indicates that the total factor productivity level of the university running efficiency in the western region has improved compared with the previous period, and the efficiency has improved significantly. On the whole, it tends to be optimized. By improving their own resource allocation ability and management technology level, colleges and universities can correspondingly transform various school running resource inputs into more optimized school running output, so as to maximize the utilization of resources, which also corresponds to the requirements of our current high-quality development of higher education.

Figure 1 time trend chart of Malmquist index and decomposition index



(2) The provincial distribution characteristics of Malmquist index. From the overall change of total factor productivity in the western region, the average value of total factor productivity of university running efficiency in the western regions is 1.001, and there are four evaluation units less than 1, which shows that on the whole, the university running efficiency of most provinces in the western region is on the rise during 2012-2021, and the annual average production efficiency has increased by 0.1%. Among

them, Chongqing has the highest growth rate of total factor productivity, followed by Guizhou, Shaanxi and Yunnan, which means that compared with other provinces in the western region, these four provinces can effectively condense the core competitiveness of high-quality development, follow the rules of running schools, improve the quality and level of running schools, better play their role of demonstration and guidance, and effectively support the development strategy of the western region. From the perspective of technical efficiency change (effch), the change value of technical efficiency in Guizhou, Tibet, Gansu, Qinghai, Ningxia and Xinjiang is less than 1, which means that the technical efficiency of colleges and universities in these provinces has declined, while the technical efficiency of other provinces has remained unchanged or improved. From the perspective of techch, Chongqing has the fastest speed of technological progress, thus the efficiency of colleges and universities has been improved the fastest, and its total factor productivity ranks first; Except Xinjiang, the change value of technological progress in other provinces is greater than 1, indicating that the technology of running colleges and universities in the vast majority of provinces in the western region is in a state of continuous innovation. From the perspective of pure

technical efficiency change (pech), except Ningxia, the change value of pure technical efficiency in other provinces is greater than 1, which means that integrated management and technology improvement play a positive role in improving total factor productivity. From the perspective of scale efficiency change (sech), Guangxi, Sichuan, Yunnan and Shaanxi are among the top in total factor productivity due to their obvious advantages in scale efficiency, which means that the scale of colleges and universities in these provinces plays a role in promoting total factor productivity.

Table 4 Malmquist index and its decomposition index of different provinces in the western region from 2012 to 2021

DMU	effch	techch	pech	sech	tfpch	rank
DMU1	1.000	1.001	1.001	0.999	1.001	7
DMU2	1.000	1.001	1.000	1.000	1.001	8
DMU3	1.000	1.006	1.000	1.000	1.006	1
DMU4	1.000	1.002	1.000	1.000	1.002	5
DMU5	0.999	1.004	1.000	0.999	1.003	4
DMU6	1.001	1.004	1.000	1.001	1.004	2
DMU7	0.997	1.002	1.000	0.997	0.999	9
DMU8	1.000	1.003	1.000	1.000	1.003	3
DMU9	0.998	1.003	1.000	0.998	1.001	6
DMU10	0.995	1.000	1.000	0.995	0.995	12
DMU11	0.996	1.003	0.999	0.997	0.999	10
DMU12	0.998	0.999	1.000	0.998	0.997	11
mean	0.999	1.002	1.000	0.999	1.001	-

Note: it is obtained from the operation results of Malmquist index model.

5.Conclusions and suggestions

5.1 Conclusion

Based on the relevant input-output data of colleges and universities in the western region from 2012 to 2021, and on the basis of previous studies, this paper designs an evaluation index system for the efficiency of running colleges and universities, and calculates the efficiency of running colleges and universities in the western region

From the static analysis results of the efficiency of colleges and universities in the western region, the overall efficiency of colleges and universities in the western provinces was in a non effective state during the sample study period, indicating that there were some problems in the allocation and management of college running resources in the western region. The mean value of pure technical efficiency is relatively high, and 70.8% of the decision-making units achieve pure technical efficiency, which shows that under the condition of limited educational resources in the western region, the ability of each decision-making unit to maximize output with a given input is relatively high. The vast majority of decision-making units are in the state of constant or increasing returns to scale, which means that the development of higher education in the western region urgently needs to increase support and make up for shortcomings.

From the dynamic analysis results of the efficiency of colleges and universities in the western region, the overall change of the efficiency of colleges and universities in the western region fluctuates relatively large, and the development trend is good. This also shows the changes in the efficiency of running colleges and universities due to the changes in school resources caused by the development of economy and society. From the results of total factor productivity of school running efficiency of different decision-making units, there are great differences among provinces in the western region. Chongqing, Sichuan, Shaanxi and Yunnan rank relatively high, while Tibet, Qinghai, Ningxia and Xinjiang rank relatively low. It is necessary to actively adjust and optimize the layout system of Higher Education in the western region.

5.2 Recommendations

Based on the research conclusion, the study puts forward the following suggestions: first, strengthen policy guidance and supervision, formulate the medium and long-term development strategic plan of higher education in Western China, and clarify

the development goals and key tasks at different stages. Second, face up to the provincial gap in running colleges and universities, deepen the pairing assistance between eastern and Western Colleges and universities, make up for the shortcomings, and implement the differentiated development strategy. Third, increase investment in education, optimize resource allocation and improve management efficiency. Fourth, we should strengthen the dynamic monitoring and evaluation mechanism for the adjustment of the layout of colleges and universities, and realize the digital empowerment of education evaluation.

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Conflict of Interests

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