Research Article

Research on the Scientific Research Efficiency of Provincial Universities Based on the DEA Model

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As the main factor of China's higher education, effective evaluation of the scientific research efficiency of domestic universities is extremely significant to improve the scientific research management system of local universities, optimize the allocation of scientific research resources, and promote regional economic development. Based on the ten-year statistical data of the compilation of science and technology statistics of colleges and universities, this paper adopts the data envelopment analysis (DEA) model to study the scientific research efficiency of 31 provincial universities in Shandong Province from three dimensions: level, type, and region. The results show that, first, the overall scientific research efficiency of the sample universities is not high and takes on a downward trend; there are some differences, changes in the same direction, and level convergence in each dimension of scientific research efficiency. Second, there is a positive correlation between the comprehensive scientific research strength of the sample universities and the technical efficiency. Third, the level of regional economic development has a positive impact on the scale efficiency of scientific research, which is closely related to the technical efficiency, and there is no positive correlation between these two. Thus, the research suggests that, in the future, colleges and universities should formulate differentiated management policies, build a "Government University" two-level scientific research performance evaluation system guided by scientific research quality, change the concept of scientific research managers, and improve the ability of personnel to improve the efficiency of scientific research in colleges and universities.

1. Introduction

Universities are an important part of the scientific and technological innovation system. University researchers are an important team in China's scientific and technological innovation. Colleges and universities are important bases for scientific and technological innovation and personnel training and are boosters for the realization of innovative national strategy [1]. Local undergraduate colleges and universities are the main part of China's undergraduate colleges and universities, which accounts for about 90% and is the backbone of building a powerful country in higher education. In 2017, China put forward a major strategic

decision to build world-class university and world-class discipline and promote the development of higher education. Under the background of "Double First-Class" construction, provincial undergraduate universities play an important role in implementing the goal of moral education, supporting the innovation-driven development strategy and serving the process of economic and social development [2]. Scientific research efficiency is the key index to reflect the innovation ability and school running level of colleges and universities, which is very important for colleges and universities to improve the quality of personnel training and social service ability. Scientific research evaluation can effectively respond to social concerns, stimulate the

enthusiasm of scientific research workers, and then improve the performance of scientific research [3]. With the needs of high-quality economic development, local governments pay more attention to the scientific research investment and performance evaluation of provincial universities. Some studies show that it is of great practical significance to promote regional economic development by relying on geographical advantages and effective use of scientific and technological innovation resources of local universities, improving the efficiency of scientific research input and output, and promoting the transformation of scientific research achievements into real productivity [4].

Shandong Province is not only a big province of economy, but also a big province of education. During the 13th Five Year Plan period of China, Shandong Province has further formed a higher education system with complete levels and reasonable layout. In 2019, the province initiated eight development strategies, such as the transformation of new and old kinetic energy and then implement the classified assessment mechanism of undergraduate colleges and universities, which puts forward new opportunities and challenges for the talent training specifications and scientific and technological innovation of provincial undergraduate colleges and universities. Considered above all, this paper takes the scientific research efficiency of universities in Shandong Province as the research object and the efficiency evaluation theory as the basis; adopts Data Envelopment Analysis (DEA) model to study the comprehensive situation and development trend of scientific research efficiency in colleges and universities from the three dimensions of university level, type, and region; and analyzes the allocation and utilization rate of scientific research resources in colleges and universities, so as to provide an important reference for strengthening the scientific research management of provincial colleges and universities, optimizing the allocation of scientific research resources, and scientifically carrying out the development planning of higher education [5].

2. Literature Review

In the field of efficiency evaluation of input and output, scholars at home and abroad have used and developed a variety of models and methods of comprehensive evaluation, such as economics and operational research. The two main methods are production function method and DEA method. In 1978, Charnes, Cooper, and Rhodes, the famous American operational research scientists, proposed DEA method and established CCR model based on constant returns to scale (CRS) [6]. Then, Banker, Charnes, and Cooper proposed a BCC model based on variable return to scale (VRS) [7]. In the 1990s, DEA method began to be applied in the field of education evaluation. Thanassoulis and Dunstan [8] used the DEA method to guide the university to improve its performance; Beasley [9] analyzed the factors affecting the university teaching and research performance with DEA method. Johnes and Johnes [10] applied the DEA model to evaluate the scientific research efficiency of the department of economics in British universities and believed that the DEA model makes a positive contribution

to determining the evaluation index of scientific research performance of universities. Fandel [11] adopted DEA model to evaluate the teaching and research efficiency of universities in North Wales, Germany, and studied the allocation of government grants based on the evaluation results. Abramo et al. [12] used bibliometric data and DEA method to evaluate the scientific research efficiency of Italian universities. Baker [13] and Munoz [14] used DEA model to evaluate the efficiency of higher education institutions in the United States and Chile, respectively.

Compared with the production function method and other methods, DEA method has become the mainstream method in the research of scientific research efficiency in colleges and universities because it has the advantages of fully considering the optimal input-output scheme of decision-making units (DMU) and is constantly trying to improve the model. At present, domestic scholars use DEA method to study the scientific research efficiency of colleges and universities, mainly from the perspectives of the scientific research efficiency of colleges and universities and its influencing factors, the characteristics of provincial scientific research efficiency, and the dynamic development of scientific research efficiency of colleges and universities. First of all, this paper explores the current situation of universities and research institutions in different provinces and their influencing factors. For example, Lu and Liu [15, 16], Luo and Guo [17], Chen Jingyi and Zong [18], and Jiang et al. [19] used DEA model to comprehensively evaluate the scientific research efficiency of universities directly under the Ministry of Education and found that there was a significant inconsistency between the comprehensive strength ranking and the scientific research efficiency ranking, and some universities with weaker strength were ahead of the universities with stronger strength in scientific research efficiency. Xu [20], Li et al. [21], Shen and Zhao [22], and Liu Tianzuo [23] paid close attention to the scientific research efficiency and its influencing factors of 31 provinces and cities in China. They analyzed the correlation between the scientific research efficiency of universities and regional economy and found that there was no inevitable relationship between the scientific research efficiency of universities and regional economy. Secondly, some scholars have explored the overall situation and regional differences of scientific research efficiency of colleges and universities from the perspective of the characteristics of scientific research efficiency of provincial colleges and universities. For example, Cheng and Zhang [24] evaluated the scientific research activities of local universities in Jiangxi Province and found that the scientific research innovation performance of local universities was generally high, but some universities had the phenomenon of redundant input or insufficient output. Similarly, Liu et al. [25] used DEA model to analyze the input and output data of scientific research in colleges and universities of Heilongjiang Province and found that the development of scientific research in colleges and universities of Heilongjiang Province was unbalanced, and those colleges and universities with the largest economic input were not the best in scientific research efficiency. However, Liu and Xu [26] came to different conclusions from the research on 27 public universities in Hunan Province. They found that the overall level of scientific research input-output performance of

universities in Hunan Province was not high, but there was a positive correlation between the scientific research performance of universities at different levels and their scientific research strength. Finally, from the perspective of the dynamic development of scientific research efficiency in colleges and universities, some scholars studied the change law and dynamic evolution of scientific research efficiency through continuous attention to the scientific research development of many colleges and universities. For example, Zong and Fu [27] used the super efficiency nonradial DEA model to dynamically analyze the scientific research efficiency and its influencing factors of 59 universities under the ministry from 2006 to 2015 and concluded that the scientific research efficiency of the sample universities had made slow progress in the recent 10 years; the overall efficiency was not high, and the scale efficiency was declining.

Based on the literature review, it is found that the current researches on the scientific research efficiency of colleges and universities mainly have the following deficiencies: first, the sampling scope of existing research is relatively broad, but the researches on the scientific research efficiency of provincial public universities under the classified assessment mechanism are rare. Second, the research content mainly focuses on the description of the effectiveness of scientific research efficiency of colleges and universities and also on the provincial universities from the perspective of classification. Third, the current evaluation of scientific research efficiency is mostly based on short-term data, but the research on the long-term trend or development law of scientific research efficiency is not enough. Based on the above analysis, this paper takes Shandong Provincial undergraduate universities as the research object; quantifies and analyzes the characteristics of their scientific research efficiency; then reveals the differences of scientific research efficiency of universities at different levels, different categories, and different regions; and puts forward more scientific, systematic, and targeted solutions to improve the scientific research efficiency of provincial undergraduate universities, so as to formulate scientific research strategies for higher education authorities. All of these aim to provide valuable reference for the development of scientific research.

3. Selection of the Evaluation Model

As one of the functions of colleges and universities, scientific research has the characteristics of more input and more output, but it also has the characteristics that the general industry does not have, so it cannot be simply measured by the price in the production field [28]. The evaluation of scientific research efficiency in colleges and universities is actually based on the input-output logic to evaluate the input and output efficiency of scientific research resources in colleges and universities. It is to introduce the production efficiency evaluation of enterprise management into the field of education management. Compared with other comprehensive evaluation methods, DEA model can deal with multi-input and multioutput variables without dimensional treatment of input and output variables. The model does not need to present production function and can effectively

avoid the influence of subjective factors on the results which is the mainstream comprehensive evaluation method.

The basic idea of DEA model is to determine the relatively effective production frontier of decision-making unit (DMU) by keeping the input or output of decision-making unit (DMU) unchanged with the help of linear programming model, project each DMU to the production frontier, and evaluate whether they are effective by comparing the degree of deviation of DMU from the frontier [27]. In the following research, the CCR model and BCC model of DEA method are mainly used. We suppose there are n -th decision-making units, DMU_j , $j = 1, 2, 3, \dots, n$, $X_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T$, $Y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^T$, $j = 1, 2, 3, \dots, n$, are the variables of input and output of decision-making units DMU_j , and the evaluation of scientific research efficiency model (CCR) is expressed as the following formula:

$$\begin{aligned} & \min \theta \\ & \text{s.t.} \left\{ \begin{array}{l} \sum_{j=1}^n \lambda_j X_j \leq \theta X_0 \\ \sum_{j=1}^n \lambda_j Y_j \geq Y_0 \\ \lambda_j \geq 0 \\ j = 1, 2, 3, \dots, n \\ \theta \text{ unconstrained} \end{array} \right\}. \end{aligned} \quad (1)$$

In model, DMU_j ($j = 1, 2, 3, \dots, n$) is the j -th. DMU , (X_j, Y_j) is input and output of DMU_j . m, s are the element numbers of two vectors $X_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T$ and $Y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^T$.

CCR model can determine whether DMU possesses technology efficiency and scale efficiency simultaneously. The final value θ is comprehensive technical efficiency or technical efficiency (TE). If $\theta = 1$, DMU is effective decision-making unit; if $\theta < 1$, DMU is invalid decision-making unit.

The BCC model decomposes technical efficiency (TE) into pure technical efficiency (PTE) and scale efficiency (SE), and its calculation formula is $TE = PTE \times SE$. BCC model is as follows:

$$\begin{aligned} & \min \theta \\ & \text{s.t.} \left\{ \begin{array}{l} \sum_{j=1}^n \lambda_j X_j \leq \theta X_0 \\ \sum_{j=1}^n \lambda_j Y_j \geq Y_0 \\ \sum_{j=1}^n \lambda_j = 1 \\ \lambda_j \geq 0 \\ j = 1, 2, 3, \dots, n \\ \theta \text{ unconstrained} \end{array} \right\}. \end{aligned} \quad (2)$$

Compared with (1) and (2), the BCC model adds a constraint on the weight λ , $\sum_{j=1}^n \lambda_j = 1$. The pure technical efficiency (PTE) can be obtained by the value of BCC model. At the same time, the scale efficiency (SE) can be calculated by dividing the technical efficiency (TE) of CCR model by the pure technical efficiency (PTE) of BCC model: $SE = TE/PTE$.

Combined with the reality of higher education in Shandong Province, based on the production efficiency evaluation logic of input-output, using DEA model and sample university data for 10 years, this paper analyzes the current situation and differences of scientific research efficiency of undergraduate universities in Shandong Province from three dimensions.

4. Data Sources and Evaluation Index System

4.1. Data Sources. Based on the fact that the main force of scientific research in provincial colleges and universities is mainly public undergraduate colleges and universities, the research samples exclude ministerial colleges and universities, private colleges and universities, independent colleges, arts and sports colleges, and special types of colleges and universities. At the same time, considering the integrity, representativeness, and accessibility of the sample data of colleges and universities, 31 provincial public undergraduate colleges and universities are selected as the research samples. The sample data are all based on the 2009–2018 “*University Science and Technology Statistical Data Collection*” issued by the Ministry of Education. According to the three dimensions of university level, category, and region, 31 sample universities are classified as follows.

The sample universities are classified according to the level dimension. In 2019, Shandong Province promulgated the implementation plan for classified assessment of undergraduate colleges and universities in Shandong Province (for Trial Implementation). According to the talent needs of different levels in Shandong Province, it is divided into three types: class I (universities with doctoral degree granting authority), class II (universities with master’s degree granting authority), and class III (other undergraduate universities). Referring to the classification method in the implementation plan, the sample universities are divided into three categories according to the level, which are called class I universities, class II universities, and class III universities. The specific classification is shown in Table 1.

The sample universities are classified by type dimension. According to the type of selected sample universities, the sample universities are divided into six categories: comprehensive, science and engineering, normal, agriculture and forestry, medicine, and finance and economics. The specific classification is shown in Table 2.

The sample universities are classified by regional dimension. According to the method of geographical division, Shandong Province is divided into three regions: Eastern Shandong (Qingdao, Yantai, Weihai, Weifang, and Rizhao), Central Shandong (Jinan, Jinan, Tai’an, Zibo, Linyi, and Dongying), and Western Shandong

(Liaocheng, Dezhou, Binzhou, Heze, and Zaozhuang). The universities are classified according to their regions, as shown in Table 3.

4.2. Evaluation Index System. Scientific and effective evaluation index is the core of scientific research efficiency evaluation in colleges and universities. This paper mainly considers the input and output of scientific research activities. According to the classical Griliches-Jaffe knowledge production function model, scientific research innovation is regarded as the product of material capital and human capital in the process of knowledge production. Therefore, based on the principles of accessibility, continuity, scientificity, and representativeness of data, this paper summarizes the research indicators of scientific research efficiency in colleges and universities in Shandong Province. Combined with the reality of scientific research in colleges and universities in Shandong Province, the input indicators of scientific research efficiency are selected as “Teaching and Research Personnel (X1),” “Expenditure of Science and Technology Funds in the current year (X2),” and “Expenditure of Science and Technology Projects Funds in the Current Year (X3).” The output indicators of scientific research efficiency are as follows: four indicators are selected, including “Paper (Y1),” “Monograph (Y2),” “Income of Technology Transfer in the Year (Y3),” and “Award (Y4).” The specific index system is shown in Table 4.

5. Analysis of Empirical Results

Theoretically speaking, technical efficiency is the product of pure technical efficiency and scale efficiency. Technical efficiency refers to the comprehensive measurement and evaluation of the resource allocation ability and resource utilization efficiency of the decision-making unit. Here, it is mainly used to measure the allocation ability and utilization efficiency of scientific research input elements. The closer the value is to 1, the more effective the technical efficiency is; pure technical efficiency refers to the efficiency brought about by the improvement of system and management level, which mainly reflects the scientific and technological efficiency of colleges and universities. The better the operation and management level of research mechanism is, the closer the value is to 1, and the more effective the pure technical efficiency is; scale efficiency refers to the difference between the existing scale and the optimal scale under the premise of a certain system and management level, which mainly reflects whether the input factors of scientific research resources in colleges and universities reach the optimal scale. The closer the value is to 1, the more effective the scale efficiency is [24, 29, 30]. Using DEA analysis software MaxDEA ultra 8.0, this paper uses the scientific research statistics of 31 sample universities from 2009 to 2018 and the investment oriented CCR and BCC models for analysis.

5.1. Comprehensive Analysis of Scientific Research Efficiency. Figure 1 shows the changes of the average technical efficiency, pure technical efficiency, and scale efficiency of the sample

TABLE 1: Classification of sample universities by the level dimension.

Level	School name				Number
I	SDUST	QDU	QUT	SDNU	11
	JUN	QUST	SDUT	QFNU	
	SDAU	SDUTCM	SDUFE		
II	LDU	SDJZU	LCU	SDYBU	11
	YTU	WFMU	BMU	LYU	
	QLUT	QAU	SDFMU		
III	WFU	DZU	TSU	HZU	9
	SDJTU	BZU	JNU	UZZ	
	JMU				

TABLE 2: Classifications of sample universities by the type dimension.

Type	School name				Number
Finance and economics	SDUFE	SDYBU			2
Science and engineering	SDUST	QUT	SDJZU	QUST	7
	SDUT	QLUT	SDJTU		
Agriculture and forestry	SDAU	QAU			2
Normal	SDNU	QFNU			2
Medicine	SDUTCM	SDFMU	JMU	WFMU	5
	BMU				
	JUN	YTU	WFU	QDU	
Comprehensive	LCU	DZU	LDU	LYU	13
	BZU	TSU	JNU	HZU	
	UZZ				

TABLE 3: Classification of sample universities by the regional dimension.

Region	School name				Number
Eastern Shandong	SDUST	QDU	QAU	QUST	11
	QUT	YTU	LDU	BMU	
	SDYBU	WFU	WFMU		
	SDNU	SDJZU	QLUT	SDUFE	
Central Shandong	SDUTCM	JUN	QFNU	JMU	15
	JNU	SDUT	SDAU	TSU	
	SDFMU	LYU	SDJTU		
Western Shandong	LCU	DZU	BZU	HZU	5
	UZZ				

universities from 2009 to 2018. The values of comprehensive technical efficiency, pure technical efficiency, and scale efficiency from 2009 to 2018 are shown in Table 5.

From the static perspective of scientific research efficiency, the average of technical efficiency, pure technical efficiency, and scale efficiency of 31 universities in the past 10 years are 0.737, 0.796, and 0.918, respectively, which are not effective. From the average of technical efficiency, we can see that the overall situation of scientific research efficiency of Shandong Provincial universities is not good. It also further indicates that the overall scientific research efficiency has great space for improvement. From the perspective of scale efficiency and pure technical efficiency, both the annual average scale efficiency and the 10-year average scale efficiency are significantly higher than the pure technical efficiency, which indicates that the pure technical efficiency mainly affects the scientific research efficiency of colleges and universities. The future work focus of colleges and universities is not simply to optimize the input of

various scientific research elements, but to rely on the system and management, with the help of connotative development path, to improve the scientific research efficiency, scientific research management level, and effective utilization level of scientific research input factors.

From the dynamic perspective of scientific research efficiency, it can be seen from Table 5 that the overall technical efficiency of colleges and universities in the past 10 years is relatively low and basically remains below 0.8, which indicates that the technical efficiency has a large space to improve. The scale efficiency is relatively stable and basically remains above 0.9, indicating that the allocation efficiency of scientific research elements is relatively high. On the whole, technical efficiency, pure technical efficiency, and scale efficiency take on a downward trend and change in the same direction in a wavy line, and there is a positive correlation among them to a certain extent. The efficiency of scientific research fluctuated greatly in 2012 and 2013, which may be

TABLE 4: Evaluation index system of the scientific research efficiency of sample universities.

First-level index	Second-level index	Third-level index
Investment	Personnel of scientific research	Teaching and research personnel (X1)
	Funds	Expenditure of science and technology funds in the current Year (X2)
		Expenditure of science and technology projects funds in the current year (X3)
Production	Technological achievements	Paper (Y1)
		Monograph (Y2)
	Social services	Income of technology transfer in the year (Y3)
	Research award	Award (Y4)

FIGURE 1: Comprehensive analysis of scientific research efficiency of sample universities.

TABLE 5: Comprehensive analysis of scientific research efficiency.

Year	TE	PTE	SE
2009	0.882	0.902	0.976
2010	0.779	0.818	0.945
2011	0.760	0.806	0.948
2012	0.611	0.692	0.884
2013	0.613	0.697	0.866
2014	0.793	0.836	0.946
2015	0.760	0.816	0.921
2016	0.747	0.808	0.918
2017	0.743	0.781	0.939
2018	0.686	0.802	0.838

related to the impact of the reform of some universities on the stability of personnel and scientific research funding. For example, the investment in teaching and scientific research personnel decreased by 2.8% and funding decreased by 3% in 2012 compared with 2011. As can be seen from Figure 1, there is little difference between technical efficiency and pure technical efficiency, while scale efficiency maintains a high level and is basically stable, which indicates that investment scale factor is the main driving force of scientific research efficiency level, and the improvement of university scientific research management system and enhancement of connotation construction of scientific research management become the main ways to improve scientific research efficiency.

5.2. Analysis from the Level Dimension. Referring to the classification method of Shandong Province undergraduate university assessment classification implementation plan, the universities with the right to confer doctor's degree, master's degree, and bachelor's degree are divided into three categories according to the level dimension, including 11 universities of class I, 11 universities of class II, and 9 universities of class III. The analysis results of average technical efficiency, average pure technical efficiency, and average scale efficiency of universities at all levels are shown in Figure 2. The technical efficiency values of level I, level II, and level III universities from 2009 to 2018 are shown in Table 6.

FIGURE 2: Line chart of technical efficiency of sample universities (level dimension).

From the static perspective of scientific research efficiency, the average 10-year technical efficiency of the three levels of colleges and universities are 0.791, 0.722, and 0.690, respectively, which are in the state of technical inefficiency, and the technical efficiency of each level is not high. From the analysis of the average ranking of technical efficiency in the past 10 years, class I universities rank first, class II universities rank second, and class III universities rank third, which shows that there is a positive correlation between the comprehensive strength of scientific research and the average of technical efficiency. It can be seen from Figure 2 that there are great differences in technical efficiency among different levels of universities, especially between 2012 and 2014, 2016 and 2018, which may be related to the adjustment of some universities during the period and the deepening of comprehensive reform of higher education proposed in 2016. Based on the analysis of the average of pure technical efficiency and scale efficiency in 10 years, the technical efficiency of class II universities is mainly affected by pure technical efficiency, while that of class III universities is mainly affected by scale efficiency, which indicates that the improvement of scientific research efficiency of class II universities should focus on strengthening scientific research management and that of class III universities should focus on optimizing the input of scientific research resources.

From the dynamic perspective of scientific research efficiency, it can be seen from Table 6 that the technical efficiency of the three levels of colleges and universities shows a downward trend in varying degrees, among which the most obvious is class III colleges and universities, from 0.911 to 0.463. Comparatively speaking, the technical efficiency of class I colleges and universities is relatively stable, and the decline is the least obvious. During the 10 years, the average of scale efficiency of the three levels of universities is greater than the average of pure technical efficiency, and the scale efficiency of class I and class II universities is basically

stable at above 0.9, which indicates that the change of technical efficiency of class I and class II universities is mainly affected by pure technical efficiency. Further analysis shows that the technical efficiency of class II colleges and universities has been in a rapid decline state from 2009 to 2013, reaching the lowest point of 0.486 in 2013 and then entering an upward trend. It can be seen that pure technical efficiency is the main factor affecting the change of technical efficiency of class II colleges and universities. The curve change trend also shows that after 2013, class II colleges and universities have strengthened the connotation construction and scientific research system management, and the scientific research efficiency has obviously improved. However, the technical efficiency of class III universities is mainly affected by the decline of scale efficiency.

5.3. Analysis from the Type Dimension. According to the classification of sample universities, the universities are divided into six categories. The scientific research efficiency calculated from the dimension of school type is shown in Figure 3. The technical efficiency values of six types of universities from 2009 to 2018 are shown in Table 7.

From the static point of view of scientific research efficiency, through the analysis of the average ranking of the technical efficiency of universities in the past 10 years, the average technical efficiency of agriculture and forestry, finance and economics, science and engineering, comprehensive, medicine, and normal universities are 0.842, 0.743, 0.738, 0.728, 0.726, and 0.716, respectively. Agriculture and forestry and finance and economics universities are ranked first; science and engineering, comprehensive, medicine, and normal universities are ranked middle; and medicine and normal universities are ranked second. Through the ranking analysis of the average technical efficiency and the average pure technical efficiency of six categories, the average technical efficiency and the average pure technical efficiency are basically positively correlated. In the 10-year data, the

TABLE 6: Technical efficiency of sample universities from the level dimension.

Level	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
I	0.887	0.769	0.772	0.750	0.758	0.884	0.770	0.725	0.785	0.811
II	0.854	0.775	0.676	0.519	0.486	0.748	0.787	0.819	0.814	0.745
III	0.911	0.796	0.849	0.554	0.590	0.737	0.714	0.685	0.605	0.463

FIGURE 3: Line chart of technical efficiency of sample universities (type dimension).

TABLE 7: Technical efficiency of sample universities from the type dimension.

Type	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Finance and economics universities	1.000	0.770	0.840	0.735	0.528	1.000	0.530	0.559	0.648	0.820
Science and engineering universities	0.925	0.762	0.749	0.630	0.589	0.774	0.760	0.711	0.706	0.779
Agriculture and forestry universities	0.938	0.769	0.839	0.752	0.514	0.767	0.959	1.000	0.966	0.913
Normal universities	0.820	0.592	0.587	0.457	0.892	0.814	0.735	0.636	0.835	0.789
Medicine universities	0.838	0.740	0.782	0.464	0.482	0.682	0.822	0.845	0.811	0.792
Comprehensive universities	0.859	0.835	0.760	0.641	0.661	0.814	0.744	0.735	0.703	0.525

average technical efficiency of agricultural and forestry universities is the highest, which is only 0.842, reflecting the poor overall technical efficiency of universities. In addition, it can be seen from Figure 3 that there are obvious differences in scientific research efficiency among the six categories, especially in the period of 2015–2017.

From the dynamic perspective of scientific research efficiency, there are great differences in the change trend of technical efficiency of various universities, and each has its own characteristics. Before 2014, the change of technical efficiency of various types of colleges and universities has a certain degree of convergence, and then the change trend has different directions. The technical efficiency of agriculture and forestry, finance and economics, normal universities, and medicine universities fluctuated the most in the past 10 years. For example, it can be seen from Table 7 that the average technical efficiency of agriculture and forestry universities with the highest average dropped from 0.938 to 0.538 in 2009–2013 and then rose to 1.000 in 2016. Other finance and economics, normal, and medicine universities also have similar rules. Although the technical efficiency of science and engineering and comprehensive universities

fluctuates, there is a strong convergence between the two types of technical efficiency, and the difference is not obvious.

5.4. Analysis from the Region Dimension. The region of the sample universities can be divided into three categories, and the scientific research efficiency is calculated from the regional dimension of universities, as shown in Figure 4. The technical efficiency values of universities in the three regions from 2009 to 2018 are shown in Table 8.

From the static perspective of scientific research efficiency, the average technical efficiency of colleges and universities in eastern Shandong, central Shandong, and western Shandong is 0.741, 0.722, and 0.772, respectively. The average scientific research efficiency of colleges and universities in three different regions is in the technical inefficiency. From the average of technical efficiency and pure technical efficiency, universities in western Shandong rank first, universities in eastern Shandong rank second, and universities in central Shandong rank third. However, from the perspective of Shandong's economic development level,

FIGURE 4: Line chart of technical efficiency of sample universities (region dimension).

TABLE 8: Technical efficiency of sample universities from the region dimension.

Region	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Eastern Shandong	0.866	0.815	0.737	0.646	0.619	0.783	0.733	0.698	0.737	0.771
Central Shandong	0.885	0.747	0.743	0.546	0.582	0.764	0.756	0.805	0.750	0.661
Western Shandong	0.909	0.797	0.861	0.732	0.690	0.900	0.832	0.679	0.737	0.579

eastern Shandong, central Shandong, and western Shandong decrease in turn, which reflects that there is no positive correlation between technical efficiency and local economic development level and also shows that western Shandong is relatively weak in economic development. However, the effective utilization rate of scientific research input elements is high, and the money is really “spent on the blade.” The economic development level of eastern Shandong and central Shandong is the highest, and the scale efficiency is relatively high, but its technical efficiency is not the best, which indicates that the scientific research management system and management level of universities in eastern Shandong and central Shandong are not high, which makes a large number of scientific research resources accumulate and causes a waste of scientific research resources. Its management level has great room for improvement. In addition, it can be seen from Figure 4 that there are some differences in technical efficiency among different regions.

From the dynamic perspective of scientific research efficiency, the scientific research efficiency of the three regions shows a downward trend in the fluctuation during the 10 years, and the descending range from large to small is western Shandong, central Shandong, and eastern Shandong. On the whole, from 2009 to 2015, although there are different degrees of differences in the scientific research efficiency of universities among the three regions, the change trend is basically the same. From 2016, the change trend of scientific research efficiency of the three regions is quite different, but the level of technical efficiency has convergence. From 2009 to 2015, it can be seen from Table 8 and Figure 4 that the technical efficiency of western Shandong has always been ahead of eastern Shandong and central Shandong, which is driven by pure technical efficiency. Since 2016, the pure technical efficiency of universities in central

Shandong and eastern Shandong has been significantly improved, but the scale efficiency of western Shandong has not been significantly improved, so the scientific research efficiency of western Shandong gradually lags behind eastern Shandong and central Shandong.

6. Conclusion and Discussion

Data envelopment analysis (DEA) is an effective method to analyze the efficiency of scientific research in colleges and universities. This paper analyzes the overall situation, dynamic trend, and differences of scientific research efficiency of the sample colleges and universities from three dimensions of level, type, and region, which has a certain reference and inspiration significance for the research of scientific research efficiency in local colleges and universities. By analyzing the statistical data of science and technology of 31 sample universities in Shandong Province from 2009 to 2018, the conclusion can be drawn as follows:

- (1) The overall level of scientific research efficiency of undergraduate universities in Shandong Province is not high and takes on a downward trend of fluctuation; different dimensions of scientific research efficiency show a certain degree of difference, changing in the same direction and level convergence. Through data analysis, the average technical efficiency of the sample universities in the past 10 years is only 0.737, which makes it obvious that the overall research efficiency is not good, and the average technical efficiency drops from 0.882 to 0.686. Although the input of scientific research elements in universities gradually increases, the research efficiency does not increase. This is mainly because the

education authorities pay more attention to connotative development in recent years, while the high quality and mass production of local universities are deficient. Therefore, great importance should be attached on universities and education authorities. From the three dimensions of level, type, and region, the average technical efficiency of universities in different levels ranges from 0.791 to 0.690; the technical efficiency of universities in different types ranges from 0.842 to 0.716; the technical efficiency of universities in different regions ranges from 0.772 to 0.724, which shows the efficiency differences in different dimensions. Further analysis found that, from the level dimension, before 2014, the technical efficiency of class II and class III universities had the same trend of change. From the category dimension, the technical level of scientific research efficiency of various types of universities had a certain degree of convergence during 2009–2014. From the regional dimension, during 2009–2015, the scientific research efficiency of eastern Shandong, central Shandong, and western Shandong had the same trend of change, but there was no significant difference. After 2016, the technical efficiency level of universities in the three regions showed convergence.

- (2) There is a positive correlation between the comprehensive strength of scientific research and the efficiency of scientific research. According to the ranking analysis of the average technical efficiency of colleges and universities at all levels, the average technical efficiency of class I colleges and universities, class II colleges and universities, and class III colleges and universities decreases in turn, which indicates that colleges and universities with higher degree awarding power not only have relatively superior resources and conditions in terms of talents, funds, projects, platforms, and other aspects, but also have relatively high level of scientific research management and utilization efficiency of scientific research elements. The efficiency of scientific research is also higher. From the microperspective of literature 10 to literature 14, the research shows that there may be inconsistency between the scientific research strength and the scientific research efficiency of specific universities. However, from the macroperspective of classification and statistics, this paper finds that there is a positive correlation between the comprehensive scientific research strength and the scientific research efficiency at the level of universities, which also reflects that the scientific research work of universities with higher degree awarding power has a higher degree of awarding power good demonstration effect.
- (3) The level of regional economic development has a positive impact on the scale efficiency of regional university scientific research, but has no positive correlation with the technical efficiency of university scientific research. The results show that the higher

the level of economic development, the higher the allocation efficiency of scientific research resources. It shows that the level of regional economic development has a positive impact on the level of scientific research investment and the allocation efficiency of scientific research resources. According to the average analysis of technical efficiency of universities in three regions, the technical efficiency of universities is the highest in western Shandong, followed by eastern Shandong, and the lowest in central Shandong, which indicates that the level of regional economic development does not match the level of scientific research efficiency of universities in the region.

In view of the current situation of the analyses, the following suggestions are put forward.

First, according to the differences of scientific research efficiency in different dimensions, different strategies should be used to achieve “targeted poverty alleviation.” Education authorities and universities should face up to the differences of scientific research efficiency in different dimensions, formulate policies according to different dimensions and different development stages, implement differentiation strategies, achieve “targeted poverty alleviation,” and promote the improvement of scientific research efficiency as a whole. From the perspective of hierarchy, the input of scientific research elements in class I and class II universities is relatively stable and at a high level, while the input of scientific research elements in class III universities is not stable enough. Therefore, class I and class II universities should focus on improving the utilization rate of scientific research elements, while class III universities should strengthen the input of scientific research elements, create a good academic environment, and improve the relevant academic system degree. From the perspective of type dimension, the efficiency of each type of scientific research is quite different, showing different characteristics. According to the actual social and economic development, we should further optimize the discipline structure, stabilize the allocation efficiency of personnel, funds and other scientific research elements in financial and comprehensive universities, ensure the continuity and stability of the input of scientific research elements, and strengthen the scientific research management team and scientific research team in agricultural and forestry, normal, and medical universities. The stability of technical personnel and scientific research management system can stimulate the vitality of scientific research personnel and system, give full play to the advantages of traditional disciplines, find the growth point of interdisciplinarity, and improve the efficiency of scientific research. From the perspective of regional dimension, the economic development level of central and eastern Shandong is high, and universities in the region have inherent advantages in talent introduction and fund investment, but they should pay attention to improving the matching degree of scientific research elements input and scientific research output, promote the effective use of scientific research resources, and realize the maximum benefit of scientific

research resources. At present, universities in western Shandong make good use of limited human and financial resources, and the next step is to increase the input of talents, funds, and other research elements according to their own development needs, learn from the advanced experience of brother universities, create a good academic atmosphere, and improve the operation mechanism of scientific research.

Second, a two-level scientific research performance evaluation system of “Government University” guided by scientific research quality should be established. Local universities account for more than 90% of the national universities, and their poor research efficiency has a great impact on the development of higher education. To improve the efficiency of scientific research in colleges and universities, it is necessary to establish two levels of evaluation mechanism oriented by the quality of scientific research. At the government level, starting from serving the local economic development, we should promote the transformation of the government’s performance evaluation mechanism from focusing on quantity and scale to focusing on quality, improve the evaluation index system, improve the comprehensive evaluation method of combining process and result, promote the transformation ability of scientific and technological innovation, and strengthen the quality-oriented scientific research while improving the scientific research policy support and increasing the input of scientific research elements. Quantity-oriented scientific research performance appraisal can stimulate the internal driving force of connotative development of colleges and universities and guide colleges and universities to establish a correct scientific research value orientation. At the level of colleges and universities, we should strengthen “breaking the only five standards” and strengthen the cultivation of scientific research talents. Taking “breaking the only five standards” as a breakthrough, we should reform the evaluation system of university teachers’ professional titles; build an index system with the quality of scientific research output, social influence, and scientific and technological innovation transformation ability as the core; guide teachers’ personal scientific research output from the number of papers, funding scale, and other indicators to the representativeness of achievements, social influence, and social service ability; and guide teachers’ scientific researchers to “write papers” on the land of the motherland. At the same time, we should strengthen the training of scientific research talents; improve the multilevel and diversified management system, operation mechanism, and incentive policy; increase the investment capital and use efficiency management of talents; and improve the output ability of personal achievements of talents.

Third, the idea of scientific research managers should be changed, professional learning should be strengthened, and a high-level scientific research management team should be built. High level of scientific research management has a significant impact on the output of high-quality scientific research achievements. The new era puts forward new standards, new tasks, and new requirements for the scientific research management in colleges and universities and promotes the transformation of the working thinking,

working mode, and working focus of the scientific research management personnel in colleges and universities. The old idea that scientific research management is only service work in the eyes of scientific research management team should be changed, and the functions of the leading, service, and guarantee of scientific research management are fully realized. By strengthening the professional learning and training of university scientific research management team; cultivating keen cutting-edge insight, good innovative thinking ability, ability to accurately grasp policies, and good organization and coordination ability; and improving the incentive mechanism of scientific research management team, the high-quality operation of scientific research work in universities can be guided, served, and ensured.

Data Availability

The data included in this paper are available without any restriction.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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