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ARTICLE

Research on Scientific Research Performance Evaluation in Colleges and Universities Based on Malmquist Index

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ABSTRACT

Scientific research is of vital importance to the development of colleges and universities. Scientific evaluation of the scientific research performance of colleges and universities, especially the study of their dynamic performance in different time ranges, can not only promote the progress of scientific research in colleges and universities, but also contribute to the rational allocation of national educational resources. Based on the Malmquist index, using the panel data of the five-year period from 2012 to 2016, this paper evaluates the changes in the research performance of China's colleges and universities, analyzes the influencing factors of total factor productivity changes from three perspectives of time series, comparison of colleges and universities, and regional analysis, and proposes countermeasures and suggestions.

1. The Raise of the Problem

As the process of economic globalization continues to accelerate, science and technology play an important role in promoting China's economic growth. Colleges and universities are the incubation bases for China's scientific research results; therefore, it is worthwhile to evaluate the efficiency of scientific research activities in colleges and universities. The evaluation of scientific research activities in colleges and universities cannot only look at the scientific research results of output, but should analyze the efficiency problems from the perspective of input and output. Most scholars use the DEA model when studying the performance evaluation of colleges and universities, Dongping Tian, et al. (2005) [1] used the DEA method to measure the scientific research efficiency of 510 colleges and universities in China, and explained the reasons for the inefficiency of colleges and universities; ShiminSun, et al. (2007) [2] used the data envelopment analysis method to obtain the input-output efficiency of the colleges and universities, and measured the input redundancy and output deficit in non-DEA effective areas; Juan Xu, et al. (2009) [3] also used this method to evaluate the efficiency of scientific research with the colleges and universities of 31 provinces and cities in China as the decision-making unit, and concluded that the effi-

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ciency of scientific research is not necessarily related to the regional economy; Jian Pan, et al. (2016)[4] evaluated the scientific research efficiency of colleges and universities based on DEA, and compared them with the other two evaluation methods, such as the factor analysis method and the Pastor method; Lingping Qiu, et al. (2017) [5] made a comprehensive analysis of DEA model to analyze and evaluate the scientific research performance of 32 agricultural universities in China; Genshu Lu et al. (2004) [6] used data envelopment analysis method to evaluate the scientific research performance of universities directly under the Ministry of Education, and proposed improvement measures for non-DEA effective decision-making units. According to the literature, there are many studies on the performance evaluation of colleges and universities, however, the research and analysis from the efficiency level is not deep enough. Most of the research methods are at the static level. The inter-period dynamic analysis of colleges and universities is also very important. In order to explore the dynamic trends and laws of scientific research efficiency in China's colleges and universities, this paper conducts a dynamic evaluation of the scientific research efficiency of colleges and universities based on the Malmquist index.

2. Research Objects and Data Sources

The data of this research are from 2012-2016 "Compilation of Basic Statistics of Colleges and Universities Directly Subordinate to the Ministry of Education", various colleges and universities, and the portal website of the Ministry of Education. Using the panel data of 75 colleges and universities with a time span of five years, the research on the performance evaluation of time series analysis, comparative analysis and regional analysis of each colleges and universities were carried out.

2.1 Construction and Data Source of Input-Output System

With 72 colleges and universities directly subordinate to the Chinese Ministry of Education as the research objects, because the branch schools of China University of Petroleum, China University of Mining and Technology, and China University of Geosciences can be used as independent samples, there are 75 data samples in this research. In the choice of input-output indicators, input indicators are mostly divided into three aspects: human input, material input and financial input. Most of the output indicators include academic achievements, scientific and technological talents, and transformation of results. Based on these indicators and the actual availability of colleges and universities data, this research constructs the following input-output indicator system, in which the input indicators are: of the total number of research and development full-time personnel, the amount of library collections, and the appropriation of scientific and technological funds; the output indicators are the number of monographs published, the number of papers published, the number of scholars in Chang Jiang Scholars Program, the number of The National Science Fund for Distinguished Young Scholars, and the actual amount of income in the year of technology transfer. The specific indicator system is shown in Table 1.

Table 1. The Input-Output System of Scientific Research Efficiency in Colleges and Universities

Input Indicators	The total number of research and development full-time personnel	X_1
	The amount of library collections	X_2
	The appropriation of scientific and technological funds	X_3
Output Indicators	The number of monographs published	Y_1
	The number of papers published	Y_2
	The number of scholars in Chang Jiang Scholars Program	Y_3
	The number of The National Science Fund for Distinguished Young Scholars	Y_4
	The actual amount of income in the year of technology transfer	Y_5

2.2 Research Methods

This paper uses the method of calculating total factor productivity to explore the scientific research efficiency of colleges and universities, and then explains the influencing factors of the research performance of colleges and universities. The Malmquist index method is a non-parametric dynamic performance evaluation method based on DEA. The Malmquist index was originally proposed by the economist Sten Malmquist (1953)[7] and used by scholars to measure changes in productivity. Later, Farrell et al. (1957) [8] combined DEA with this theory, and then the model of productivity measurement based on DEA's Malmquist index was constructed and decomposed into technical efficiency and production technology. The formula is as follows:

$$M_{RD}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_V^{t+1}(x^{t+1}, y^{t+1})}{D_V^t(x^t, y^t)} \times \left[\frac{D_V^t(x^t, y^t)}{D_V^{t+1}(x^t, y^t)} \times \frac{D_V^t(x^{t+1}, y^{t+1})}{D_V^{t+1}(x^{t+1}, y^{t+1})} \right]^{\frac{1}{2}}$$

$$\times \left[\frac{D_C^t(x^{t+1}, y^{t+1}) / D_V^t(x^{t+1}, y^{t+1})}{D_C^t(x^t, y^t) / D_V^t(x^t, y^t)} \times \frac{D_C^{t+1}(x^{t+1}, y^{t+1}) / D_V^{t+1}(x^{t+1}, y^{t+1})}{D_C^{t+1}(x^t, y^t) / D_V^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}}$$

i.e. $EC = PTEC \times SEC$, $TFP = EC \times TC$

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3. Research and Analysis of Scientific Research Performance Evaluation of Colleges and Universities Based on Malmquist Index

In order to study the changes in scientific research efficiency in different periods, the panel data of the research input and output of colleges and universities directly subordinate to the Chinese Ministry of Education in 2012-2016 were analyzed using deap2.1 software. In the five years from 2012 to 2016, the scientific research efficiency of Chinese colleges and universities generally showed a trend of rising first and then decreasing, total factor productivity is greater than 1 in 2013-2015, which indicates that the change in progress is positive, and the scientific research efficiency of colleges and universities is close to optimal. Total factor productivity is less than 1 in 2012-2013&2015-2016, which indicates that the change is negative, and the scientific research efficiency of colleges and universities is far from the optimal scale. Among them, the technological efficiency changes from 2015 to 2016 were the best, but the rate of technological progress has declined to a large extent, resulting in a decline in overall scientific research efficiency. Overall, the progress of scientific research efficiency in Chinese colleges and universities has been slow in the five years from 2012 to 2016.

Table 2. Time Series Analysis of Dynamic Scientific Research Efficiency of Chinese Colleges and Universities in 2012-2016

Year	Technical Efficiency	Rate of Technical Progress	Pure Technical Efficiency	Scale Efficiency	Total Factor Productivity
2012-2013	1.008	0.954	0.986	1.022	0.961
2013-2014	0.982	1.107	0.993	0.989	1.086
2014-2015	0.981	1.153	0.998	0.983	1.131
2015-2016	1.053	0.765	1.019	1.033	0.806
Average Value	1.005	0.982	0.999	1.007	0.988

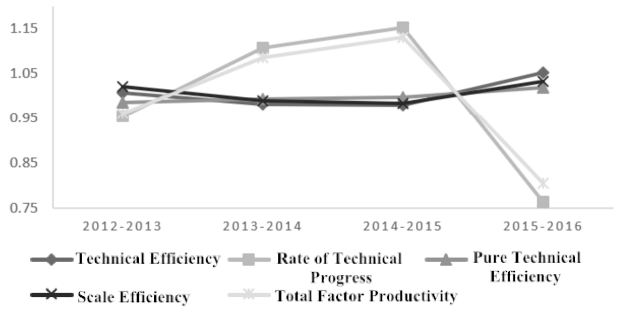

Figure 1. Time Series Analysis of Dynamic Scientific Research Efficiency of Chinese Colleges and Universities in 2012-2016

According to Figure 1, the extent and causes of the increase or decrease in the efficiency of scientific research in universities and colleges are further explained. In general, during the period of 2012-2015, the total factor productivity of scientific research in Chinese colleges and universities was growing, however, there has been a significant decline in 2015-2016, and the trend of change is the result of a combined action of technical efficiency and technological progress. We can see that the trajectory of technical efficiency is affected by pure technical efficiency and scale efficiency. The trajectory of the change of total factor productivity and the trajectory of technological progress rate are similar, and the same direction changes and the development shows instability, which shows that the rate of technological progress has a greater impact on total factor productivity. [9] China's technical efficiency fluctuations in 2012-2016 are relatively small, and there is no regularity in the changes in technical efficiency due to changes in the efficiency of scientific research. China's technical efficiency fluctuations in 2012-2016 are relatively small, and there is no regularity in the changes in technical efficiency due to changes in the scientific research efficiency.

Through the analysis of time series, we can see the overall changes of the scientific research efficiency of colleges and universities every year, and the comparative analysis of the specific indicators of the colleges and universities in 2012-2016 is shown in Table 3.

Table 3. Comparative Analysis of Dynamic Scientific Research Efficiency of Chinese Colleges and Universities in 2012-2016

Name	Technical Efficiency	Rate of Technical Progress	Pure Technical Efficiency	Scale Efficiency	Total Factor Productivity
Peking University	0.861	0.926	0.890	0.968	0.797
Renmin University of China	0.858	0.992	0.861	0.997	0.852
Tsinghua University	1.000	0.893	1.000	1.000	0.893
Beijing Jiaotong University	0.915	0.926	1.009	0.907	0.847
University of Science and Technology Beijing	0.927	0.983	0.938	0.988	0.911
Beijing University of Chemical Technology	0.975	0.926	0.985	0.991	0.903
Beijing University of Posts and Telecommunications	1.100	0.963	1.067	1.030	1.059
China Agricultural University	0.980	1.013	0.980	1.000	0.993
Beijing Forestry University	0.950	1.026	0.963	0.987	0.975

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Beijing University of Chinese Medicine	0.829	1.039	0.921	0.900	0.861
Beijing Normal University	0.949	0.974	0.951	0.998	0.925
Beijing Foreign Studies University	1.000	1.097	1.000	1.000	1.097
Beijing Language and Culture University	0.865	0.987	0.876	0.987	0.854
Communication University of China	0.837	1.019	0.842	0.994	0.853
Central University of Finance and Economics	0.940	0.928	0.942	0.998	0.872
University of International Business and Economics	1.029	1.035	0.972	1.059	1.066
Central Conservatory of Music	0.862	0.855	0.913	0.944	0.737
Central Academy of Fine Arts	0.844	0.903	0.844	1.000	0.762
The Central Academy of Drama	0.971	0.966	1.000	0.971	0.938
China University of Political Science and Law	1.086	0.940	0.968	1.122	1.021
China University of Petroleum,Beijing	1.132	0.956	1.111	1.019	1.082
China University of Petroleum, East China	1.475	0.951	1.470	1.003	1.403
North China Electric Power University	1.018	0.990	1.018	1.000	1.008
Nankai University	0.849	1.022	0.822	1.032	0.867
TianjinUniversity	0.941	1.013	0.941	1.000	0.953
Dalian University of Technology	1.070	0.979	1.064	1.006	1.048
Northeastern University	0.953	0.954	0.954	0.999	0.909
Jilin University	1.165	1.011	1.109	1.050	1.178
Northeast Normal University	1.157	1.035	1.070	1.081	1.197
Northeast Forestry University	1.009	0.966	1.000	1.009	0.975
Fudan University	1.022	1.009	0.998	1.024	1.031
Tongji University	1.115	1.033	1.103	1.011	1.152
Shanghai Jiao Tong University	0.905	0.842	0.945	0.959	0.762
East China University of Science and Technology	1.033	0.956	1.033	1.000	0.988
Donghua University	1.030	0.915	1.077	0.956	0.943
East China Normal University	1.034	0.914	0.965	1.071	0.944
Shanghai International Studies University	1.000	0.949	1.000	1.000	0.949
Shanghai University of Finance and Economics	1.007	1.081	1.002	1.005	1.088
Nanjing University	0.977	1.014	1.000	0.977	0.991
Southeast University	0.986	0.945	1.046	0.943	0.932
China University of Mining and Technology	1.198	1.048	1.155	1.038	1.255
China University of Mining &Technology,Beijing	0.683	0.947	0.686	0.996	0.647
Hohai University	0.973	1.005	0.975	0.999	0.978
Jiangnan University	1.055	1.014	1.025	1.028	1.070
Nanjing Agricultural University	0.983	0.988	0.986	0.997	0.971
China Pharmaceutical University	1.020	1.041	1.029	0.992	1.062
Zhejiang University	0.929	1.050	0.928	1.000	0.976
Hefei University of Technology	0.821	0.912	0.900	0.912	0.749
Xiamen University	0.901	0.929	0.911	0.988	0.837
Shandong University	1.173	0.924	1.069	1.097	1.084
Ocean University of China	0.977	0.973	1.000	0.977	0.950
Wuhan University	1.054	1.002	0.982	1.073	1.056
Huazhong University of Science and Technology	1.058	1.016	1.022	1.035	1.075
China University of Geosciences, Wuhan	1.116	1.041	1.096	1.018	1.161
China University of Geosciences, Beijing	0.997	0.953	0.988	1.009	0.950
Wuhan University of Technology	1.089	0.929	1.118	0.974	1.011
Huazhong Agricultural University	1.155	1.018	1.149	1.005	1.176
Central China Normal University	0.883	0.922	0.903	0.977	0.814
Zhongnan University of Economics And Law	1.246	1.012	1.035	1.204	1.260
Hunan University	1.169	1.007	1.152	1.015	1.177
Central South University	0.947	0.942	0.921	1.027	0.892
Sun Yat-sen University	0.967	0.916	0.969	0.999	0.886
South China University Of Technology	1.000	1.008	1.021	0.979	1.008
Chongqing University	0.975	1.010	0.977	0.998	0.985
Southwest University	1.211	1.060	1.091	1.110	1.283
Sichuan University	1.167	0.985	1.040	1.122	1.149
Southwest Jiaotong University	0.936	0.988	1.000	0.936	0.924
University of Electronic Science and Technology of China	1.175	1.138	1.151	1.022	1.338
Southwestern University of Finance and Economics	1.142	1.059	1.099	1.039	1.210

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Xi'an Jiaotong University	1.029	0.984	1.091	0.943	1.012
Xidian University	1.041	1.007	1.039	1.002	1.047
Chang'an University	1.127	1.011	1.080	1.043	1.139
Northwest A & F University	1.099	1.014	1.117	0.984	1.115
Shaanxi Normal University	0.939	1.014	0.908	1.034	0.952
Lanzhou University	1.041	0.992	1.024	1.016	1.032
Average Value	1.005	0.982	0.999	1.007	0.988

According to the analysis of the changing index of technical efficiency, it can be seen that, the technical efficiency index of 35 colleges and universities of China University of Mining and Technology (Beijing), Hefei University of Technology, Beijing University of Chinese Medicine, Communication University of China, Central Academy of Fine Arts, Nankai University, Renmin University of China, Peking University, and Central Conservatory of Music is less than 1, which shows that the scientific research efficiency of these colleges and universities is reduced, accounting for 46.67%.The technical efficiency of the remaining colleges and universities is greater than or equal to 1, indicating that the scientific research efficiency of colleges and universities has improved or remained the same, accounting for 53.33%. From the analysis of the change index of technological progress rate, the changing index of the technological progress rates of 42 colleges and universities in Shanghai Jiaotong University, Central Conservatory of Music, Tsinghua University, Central Academy of Fine Arts, Hefei University of Technology, East China Normal University, Donghua University, Zhongshan University and Huazhong Normal University showed a downward trend, which shows that the level of scientific research in colleges and universities has declined, accounting for 56%.The index of scientific research progress of the remaining colleges and universities has risen, indicating that the level of technology has improved, accounting for 44%.According to the observation and analysis of the index change of total factor productivity, it can be seen that, only China University of Petroleum (East China), University of Electronic Science and Technology, Southwest University, Zhongnan University of Economics and Law, China University of Mining and Technology, Southwestern University of Finance and Economics, Northeast Normal University, Jilin University, Hunan University and other 34 colleges and universities have seen the increase in total factor productivity, accounting for 45.33%. The increase in total factor productivity may be due to advances in technology and innovation, and the remaining colleges and universities have experienced a decline in total factor productivity, accounting for 54.67%.The reason for this phenomenon may be that the speed of advancement of technology is too slow, or that it is unreasonable in terms of management methods and the size of colleges and universities.

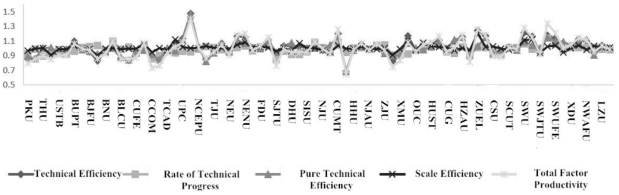

Figure 2. Comparative Analysis of Dynamic Scientific Research Efficiency of Chinese Colleges and Universities in 2012-2016

Notes: PKU: Peking University; THU: Tsinghua University; USTB: University of Science and Technology Beijing; BUPT: Beijing University of Posts and Telecommunications; BJFU: Beijing Forestry University; BNU: Beijing Normal University; BLCU: Beijing Language and Culture University;CUFE: Central University of Finance and Economics; CCOM: Central Conservatory of Music; TCAD: The Central Academy of Drama; UPC: China University of Petroleum; NCEPU: North China Electric Power University; TJU: Tianjin University; NEU: Northeastern University; NENU: Northeast Normal University; FDU: Fudan University; SJTU: Shanghai Jiao Tong University; DHU: Donghua University; SISU: Shanghai International Studies University; NJU: Nanjing University; CUMT: China University of Mining and Technology; HHU: Hohai University; NJAU: Nanjing Agricultural University; ZJU: Zhejiang University; XMU: Xiamen University; OUC: Ocean University of China; HUST: Huazhong University of Science and Technology; CUG: China University of Geosciences; HZAU: Huazhong Agricultural University; ZUEL: Zhongnan University of Economics and Law; CSU: Central South University; SCUT: South China University of Technology; SWU: Southwest University; SWJTU: Southwest Jiaotong University; SWUFE:Southwestern University of Finance and Economics; XDU: Xidian University; NWAFU: Northwest A&F University; LZU: Lanzhou University

Figure 2 shows the Malmquist scientific research efficiency index and its decomposition line graph for colleges and universities, where the abscissa is the sample colleges and universities, and the ordinate is the value of each efficiency, it can be seen from the figure that the index of total factor productivity of scientific research in most colleges and universities shows obvious fluctuations, and the changes of total factor productivity are almost the same as the changes track of technological progress rate. However, the index changes of technical efficiency, pure technical efficiency and scale efficiency are more complicated, and there is no obvious regularity.

Through the measurement and analysis of the technical efficiency, technological progress rate, pure technical efficiency, scale efficiency, and total factor productivity of colleges and universities, we compared the changes in scientific performance between colleges and universities for the five years from 2012 to 2016 and analyzed the reasons for the fluctuations. According to Table 4, we further

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analyze the regional changes in the scientific research efficiency of Chinese colleges and universities. According to the analysis of the technical efficiency change index, it can be seen that, the scientific research efficiency in the western region has been the highest, and the technical efficiency has increased by 7.15% in five years, followed by the central region, the technical efficiency increased by 1.60% in the five years, and finally the eastern region experienced a decline in technical efficiency. According to the analysis index of the rate of technological progress, only the technical level of the western region has improved in the past five years, which has increased by 1.89%. The rate of technological progress in other regions has declined, with the central region dropping the most, followed by the eastern region. Through the analysis of the changing index in total factor productivity, it was found that only the western region increased, with a growth of 9.36% in five years, and there was a decrease of 0.92% and 3.30% in the central and eastern region, respectively. Combined with the line chart of Figure 3, we can make further analysis more intuitively, from a regionally perspective; all kinds of indicators are optimized for the scientific research efficiency of colleges and universities in the western region from 2012 to 2016, while the innovation and development of traditional scientific research areas are lagging behind.

Table 4. Regional Analysis of Dynamic Scientific Research Efficiency of Chinese Colleges and Universities in 2012-2016

Region	Technical Efficiency	Rate of Technical Progress	Pure Technical Efficiency	Scale Efficiency	Total Factor Productivity
Eastern Region	0.991	0.976	0.989	1.002	0.967
Central Region	1.016	0.969	1.008	1.004	0.991
Western Region	1.072	1.019	1.044	1.025	1.094

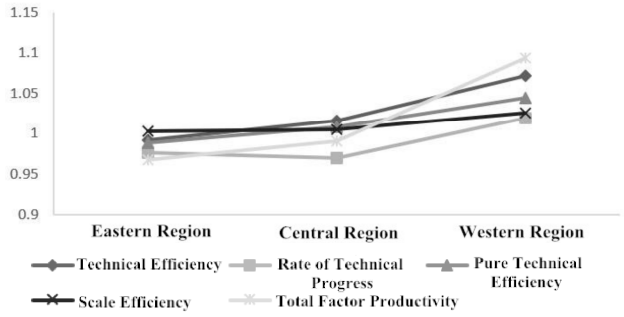

Figure 3. Regional Analysis of Dynamic Scientific Research Efficiency of Chinese Colleges and Universities in 2012-2016

4. Conclusion and Suggestion

4.1 Conclusion

This paper uses the efficiency index analysis method of Malmquist based on DEA model to analyze the scientific research efficiency of 75 colleges and universities directly subordinate to the Ministry of Education from 2012 to 2016.The paper decomposes total factor productivity into changes in technical efficiency and technological progress rate to study the factors that influence the internal efficiency of research, the trend of change, and the comparison between different colleges and universities and between regions. The following conclusions were drawn:

(1) The scientific research efficiency of China's colleges and universities showed a steady growth from 2012 to 2015.However, from 2015 to 2016, due to the decline in the technology progress index, total factor productivity increased from 13.1% at the end of 2015 to a decrease of 19.4% at the end of 2016.

(2) The total factor productivity of Chinese colleges and universities is quite different. The main reason is that the index of technological change between colleges and universities is quite different. The technological progress change index and the total factor productivity change index of colleges and universities show similar trajectories and trends, and the technical efficiency is around 1.00. The fluctuation range is small and the change is relatively stable.

(3) From the comparative analysis of the regional scope, the scientific research efficiency changes in the western region are closer to the optimization frontier, followed by the central region and finally the eastern region.

4.2 Suggestion

In order to promote the steady growth of scientific research efficiency in China's colleges and universities, the following Suggestions are put forward:

(1) Understand the Gap in Scientific Research Efficiency and Strengthen Inter-school Regional Cooperation

Relevant authorities should understand the differences in scientific research efficiency between the colleges and universities, the provinces, and the policy incentives for less efficient colleges and universities and regions. At the same time, colleges and universities should also understand their own scientific research strengths and weaknesses, learn from the benchmarks and universities, and conduct scientific research cooperation through the form of talent exchange.

(2) Adjust the Scale of Input Factors to Achieve Rational Resource Allocation

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In order to achieve steady growth in national colleges and universities, it is necessary to increase the scale of scientific research investment in colleges and universities or regions with low scientific research efficiency. In addition to the state's scientific research funding appropriation, colleges and universities with low scientific research efficiency should also seek other sources of research funding, such as applying for various fund topics or consulting services related to scientific research and technology, in order to achieve rational allocation of resources.

(3) Pursue Technological Progress and Innovation, Improve Scientific Research Management Mechanism

To achieve the improvement of the total factor productivity of scientific research activities, the most important thing is to improve the index of change in technological progress, learn new technologies, and introduce high-energy scientific research equipment, which can enhance the efficiency of scientific research activities, and dare to pursue innovation to promote technological progress. [10] Formulate high-efficiency scientific research management mode, optimize the staged process of scientific research management, and improve the scientific research management mechanism.

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