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Research on Intellectual Property Innovation Performance of Chinese Universities Based on Malmquist Index

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Abstract: Colleges and universities are an important subject in the construction of a strong country with intellectual property rights and play an important role in technological innovation. This article takes the 2018-2020 intellectual property input and output results of 32 "double first-class" universities in China as the research object, and uses the DEA model and the Malmquist index method to conduct an empirical analysis of the intellectual property operating performance of Chinese universities. The results of the study found that the intellectual property innovation efficiency of "double first-class" universities is on the rise, but the overall creation efficiency has not reached an effective state, the efficiency of achievement transformation is low, and the regional development is unbalanced. In order to further improve the efficiency of intellectual property operations in universities, improvements need to be made in terms of increasing resource input, strengthening personnel training, and rationally allocating resources.

Keywords: "double first-class" universities; intellectual property; innovation performance; DEA model; Malmquist index

1 Introduction

The future competition is the competition of intellectual property and creativity. China has always attached great importance to the protection of intellectual property rights and the cultivation of innovation capabilities. As early as 2008, the "Outline of National Intellectual Property Strategy" was issued to strengthen the construction of intellectual property in four aspects: creation, application, protection and management. In 2015, the State Council put forward guidance on strengthening the construction of intellectual property professionals in response to the lack of talents. The 14th Five-Year Plan announced in 2020 and the long-term goal for 2035 also propose to strengthen the protection of intellectual property rights and improve the scientific and technological innovation system and mechanism. With the support of policies, the overall development level of China's intellectual property rights has been significantly improved, the protection capacity has been greatly improved, and the innovation has achieved remarkable results.

As an important subject of scientific and technological innovation, universities are a key element in China's implementation of the strategy of building a strong country with intellectual property rights and rejuvenating the country through science and technology. In particular, "double first-class" universities have strong teaching staff, abundant human resources, perfect scientific research facilities, and a good academic atmosphere. They are an important force in the cultivation of talents and technological innovation in modern society. Data show that in 2019, there were 355,000 R&D personnel, 99.8 billion yuan in R&D expenditures, 136,000 patents, horizontal scientific research funding over 35 billion yuan, and the direct transaction volume of scientific and technological achievements reached 2 billion yuan in Chinese universities. Vertically, the innovation capability of Chinese universities has been significantly improved, and the transformation of scientific and technological achievements has achieved initial results. However, compared with developed countries such as Europe and the United States, China still has gaps in original creation, patent quality, and talent training. Therefore, this paper selects 32 representative "double first-class" universities, evaluates the operational performance of Chinese universities from the perspective of input and output, deeply analyzes the status quo of university intellectual

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property development, and taps the scientific research strength of universities. Finally, we will vigorously promote the construction of intellectual property rights in colleges and universities in terms of increasing resource input, strengthening talent training, and rationally allocating resources, so as to provide strong support for accelerating the construction of an innovative country.

2 Literature Review

Scholars at home and abroad have done a lot of research on the construction of intellectual property system and protection mechanism in colleges and universities. It not only has theoretical analysis, but also uses empirical materials from different universities to provide evidence for in-depth research in the field of intellectual property. In general, the existing research mainly focuses on the following three aspects: (1) Research objects of intellectual property rights in universities. Foreign scholars mostly conduct research by selecting representative comprehensive universities. For example, Flegg et al. (2004) used empirical methods to measure the efficiency of scientific research and production of 45 universities in the UK. Woethington et al. (2008) analyzed the total factor productivity of 35 universities in Australia. The research objects of domestic scholars mainly focus on two points. On the one hand, they focus on specific provinces. For example, Zhu et al. (2013) analyzed the scientific research performance of 13 universities in Shanghai. Wang et al. (2021) measured the intellectual property innovation capabilities of universities in Shandong Province. On the other hand, evaluation is made from a certain aspect of scientific research activities in universities. For example, Liu et al. (2018) believe that young teachers play an important role in scientific research performance. Hua (2021) divides university intellectual property talents into five categories, and believes that specialized talents are essential to university innovation and intellectual property protection and transformation. (2) Design of index system for intellectual property performance evaluation. Li (2014) constructs an index system to analyze the technological innovation of universities from four aspects: patent output, discipline planning, patent type, and legal awareness. Liu et al. (2018) selected 16 specific indicators from creativity, application, protection, and management capabilities to evaluate the performance of Chinese universities' intellectual property rights in accordance with China's intellectual property policies and regulations. Zhao et al. (2021) used human resources and scientific and technological funding as input indicators, and academic papers, scientific and technological monographs, scientific and technological patents, and achievement transformation as output indicators, and constructed a scientific research performance evaluation system for colleges and universities from the perspective of input and output. (3) Selection of intellectual property performance evaluation model. In the selection of the model, the preliminary research adopts a combination of qualitative and quantitative methods such as expert scoring method, analytic hierarchy process, AHP-fuzzy comprehensive evaluation method, etc. (Song et al., 2013; Zhao et al., 2013). In the later stage, DEA model is mainly selected for empirical analysis (Song, 2020).

In summary, domestic and foreign scholars have done fruitful research on the construction of intellectual property rights in universities from different perspectives. However, most of the existing research is qualitative analysis, lacking a quantitative mechanism, and a single selection of indicators, which cannot accurately and comprehensively evaluate the level of scientific research innovation and the level of intellectual property construction in Chinese universities. Therefore, on the basis of previous studies, this article has been improved and perfected from the three aspects of research object, index selection and research method. Taking 32 "double first-class" universities as the research objects, selecting input and output indicators from multiple dimensions, scientifically evaluating the scientific research and innovation capabilities of Chinese universities, introducing the Malmquist index on the basis of the DEA model, and longitudinally comparing the development trends and changing laws of scientific research performance. It also conducts a differentiated analysis between regions, analyzes the status quo of intellectual property innovation in Chinese universities from multiple angles and subjects, and provides a realistic basis for managers to formulate scientific and reasonable scientific research policies.

3 Research Design

3.1 Model introduction

(1) DEA model

The DEA model adopts linear programming and does not need to set specific functional forms and distribution assumptions. It can handle multiple input and multiple output variables and perform efficiency decomposition. It is widely used in the study of multi-agent operation efficiency. Because of the large differences in operating efficiency between the "double first-class" universities, this paper chooses the BCC model. This model splits technical efficiency (TE) into pure

technical efficiency (PTE) and scale efficiency (SE), and there is a relationship of TE=PTE*SE. Its expression is:

$$\begin{cases} Min[\theta - \epsilon(\sum_{j=1}^{m} S^- + \sum_{j=1}^{s} S^+)] \\ s.t. \sum_{j=1}^{n} \lambda_j x_j + s^- = \theta_{x_0} \\ \sum_{j}^{n} \lambda_j y_j - s^+ = y_0 \\ s^+ \geq 0, s^- \geq 0 \\ \lambda_j \geq 0, j = 1, 2, ..., n \\ \sum_{j=1}^{n} \lambda_j = 1 \end{cases} \tag{1}$$

Among them, n is the decision-making unit, m is the input, and n is the output. x_j,y_j respectively represent the input and output of the j-th decision-making unit. s^+,s^- respectively represent the introduced slack variable and residual variable. θ represents the overall efficiency value of the decision-making unit, and the value range is between 0-1. If θ = 1 and s^+=s^-=0, it means that the technology is effective, that is, the bank has the largest input-output ratio, and PTE and TE are both effective; If θ =1 and $s^+ \neq 0$ or $s^- \neq 0$, it means that the technology is weakly valid, and PTE and SE are not valid at the same time; if $\theta < 1$, the technology is invalid, and PTE and SE are invalid at the same time.

(2) Malmquist index

The DEA model can only horizontally measure the intellectual property operating performance of different universities at the same time point, and cannot perform dynamic evaluation. Therefore, based on the static analysis of the DEA model, this paper introduces the Malmquist index to measure the inter-period changes in the intellectual property innovation performance of 32 "double first-class" universities, and explains the dynamic characteristics of efficiency changes. Its expression is:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = [\frac{D_c^t(x^{t+1}, y^{t+1})}{D_c^t(x^t, y^t)} \times \frac{D_c^{t+1}(x^{t+1}, y^{t+1})}{D_c^{t+1}(x^t, y^t)}]^{\frac{1}{2}} \tag{2}$$

$$TCH = [\frac{D_c^t(x^{t+1}, y^{t+1})}{D_c^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_c^t(x^t, y^t)}{D_c^{t+1}(x^t, y^t)}]^{\frac{1}{2}} \tag{3}$$

$$ECH = \frac{D_c^t(x^{t+1}, y^{t+1})}{D_c^t(x^t, y^t)} \tag{4}$$

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = TCH \times ECH \tag{5}$$

Among them, D_c^tandD_c^{t+1} are the output functions of period t and t+1 respectively, (x^t,y^t) and (x^{t+1},y^{t+1}) are the input and output vectors. If M<1, it indicates that the total factor productivity is decreasing; M=1, the total factor productivity remains unchanged during the two periods; M>1, it indicates that the total factor productivity is increasing.

The Malmquist index can be decomposed into the technical efficiency change index (ECH) and the technical progress index (TCH). The technical efficiency change index can be further decomposed into pure technical efficiency change (PECH) and scale efficiency change (SECH). Each index is greater than 1, which means that it can improve the efficiency of technological innovation; less than 1 means that it hinders the efficiency of technological innovation; equal to 1 means that it has no effect on the efficiency of technological innovation. It can be seen that the Malmquist index can not only perform dynamic evaluation, but also further decompose the indicators, explore the evolution path and deep-seated reasons of total factor productivity, and then find the most effective improvement countermeasures.

3.2 Index selection and data sources

Based on the status quo of the development of intellectual property in Chinese universities and taking into account the availability of data, this article measures and analyzes the intellectual property innovation performance of 32 "double first-class" universities in China from 2018 to 2020. The article selects four input indicators and three output indicators.

The specific index categories and meanings are shown in Table 1. The data mainly comes from the "Compilation of Statistical Data on Scientific and Technological Activities of Colleges and Universities". Due to the lag in output, data from 2018 and 2019 are selected for input indicators, and data for 2019 and 2020 are selected for output indicators.

Table 1: Performance Evaluation Index System of Intellectual Property Operation

Indicator type	Indicator variable	Indicator type	Indicator variable
Input index	Number of R&D personnel	Output index	Number of patents granted
	R&D expenditure		Number of publications
	Number of R&D projects		Number of published papers
	Application of R&D Achievements		

4 Empirical Test

4.1 Static analysis of DEA model

This paper uses DEAP2.1 software to measure the intellectual property innovation performance of 32 "double first-class" universities in China in 2019 and 2020. The analysis results are shown in Table 2.

(1) Comprehensive technical efficiency analysis

Comprehensive technical efficiency (TE) is a key indicator that reflects the performance of intellectual property rights of "double first-class" universities. The rationality of resource allocation and the effectiveness of resource utilization are measured by measuring the input-output ratio. The closer the value is to 1, the higher the efficiency of the university's intellectual property operations and the stronger the innovation capability. It can be seen from Table 2 that in 2019, the intellectual property innovation efficiency of China's 32 "double first-class" universities was 0.838, and it rose to 0.927 in 2020. Relatively speaking, the two periods of numerical increase have increased significantly, indicating that China's implementation of "double first-class" universities can improve the university's intellectual property construction system and enhance independent innovation capabilities. However, in terms of absolute data, the DEA has not been effective, and there is still room for improvement in the future. By comparing the overall efficiency values of various universities, it can be found that there are big differences in the use of intellectual property and the ability of innovation and creativity among different universities. Except for the slight decline of Hunan University and Xi'an Jiaotong University, the performance of intellectual property operations of other universities has improved, indicating that the intellectual property construction work of Chinese universities has achieved remarkable results. In 2019, there are 10 "double first-class" colleges and universities whose comprehensive innovation efficiency has reached the forefront of production. In 2020, it will rise to 19, accounting for 31.25% and 59.38% respectively. Among them, Tsinghua University, Fudan University, Southeast University, Xiamen University, Shandong University, Ocean University of China, and University of Electronic Science and Technology of China achieved effective intellectual property operation efficiency in both periods. Show that their innovation ability and resource utilization ability have always been in the forefront.

According to the classification of the effectiveness of DEA, the operating performance of the 32 "double first-class" colleges and universities in 2020 can be divided into three levels: DEA effective, DEA weakly effective, and DEA invalid. Among them, DEA effectively includes 19 universities such as Peking University, Renmin University of China, Tsinghua University, and its comprehensive technical efficiency and decomposition indicators are always at the forefront of production. It shows that the intellectual property construction of these universities has reached a relatively ideal state, and the resources have been optimally allocated to achieve the best results. Five universities, including Shanghai Jiaotong University and Zhejiang University, belong to the DEA weakly effective. Its pure technical efficiency value is 1, but the scale efficiency is not high, resulting in the comprehensive technical efficiency not reaching there. Therefore, these 5 colleges and universities should rationally allocate the scale of input and output to promote the improvement of scale and efficiency, and further reach the effective state. Eight universities including China Agricultural University, Jilin University and Tongji University are DEA invalid. Its comprehensive technical efficiency and decomposition efficiency have not reached the effective state. There is still much room for improvement in the performance of intellectual property operations of these eight universities. It is necessary to jointly promote the improvement of the efficiency of intellectual property rights from the two aspects of internal structure and scale setting.

Table 2: Intellectual Property Operational Efficiency Values of China's "Double First-Class" Universities

University	2019				2020			
	TE	PTE	SE	Return to scale	TE	PTE	SE	Return to scale
Beijing University	0.986	1.000	0.986	irs	1.000	1.000	1.000	—
Renmin University of China	0.896	0.944	0.950	drs	1.000	1.000	1.000	—
Tsinghua University	1.000	1.000	1.000	—	1.000	1.000	1.000	—
China Agricultural University	0.725	0.751	0.965	drs	0.834	0.839	0.995	irs
Beijing Normal University	0.647	0.837	0.772	drs	1.000	1.000	1.000	—
Nankai University	0.822	0.997	0.824	drs	1.000	1.000	1.000	—
Tianjin University	0.647	0.837	0.772	drs	1.000	1.000	1.000	—
Dalian University of Technology	0.516	0.587	0.878	drs	1.000	1.000	1.000	—
Northeastern University	0.811	1.000	0.811	drs	1.000	1.000	1.000	—
Jilin University	0.836	0.880	0.944	drs	0.946	0.950	0.996	drs
Fudan University	1.000	1.000	1.000	—	1.000	1.000	1.000	—
Tongji University	0.795	0.844	0.896	drs	0.880	0.963	0.914	drs
Shanghai Jiaotong University	0.608	0.737	0.825	irs	0.846	1.000	0.846	drs
East China Normal University	0.673	0.723	0.930	drs	0.806	0.829	0.972	irs
Nanjing University	0.811	0.832	0.759	irs	0.879	0.929	0.946	drs
Southeast University	1.000	1.000	1.000	—	1.000	1.000	1.000	—
Zhejiang University	0.987	0.964	0.982	drs	0.999	1.000	0.999	drs
Xiamen University	1.000	1.000	1.000	—	1.000	1.000	1.000	—
Shan Dong University	1.000	1.000	1.000	—	1.000	1.000	1.000	—
Ocean University of China	1.000	1.000	1.000	—	1.000	1.000	1.000	—
Wuhan University	1.000	1.000	1.000	—	0.928	0.995	0.926	drs
Huazhong University of Science and Technology	1.000	1.000	1.000	—	0.893	1.000	0.893	drs
Hunan University	0.608	0.737	0.825	irs	0.608	0.611	0.996	drs
Central South University	0.936	0.852	0.964	drs	1.000	1.000	1.000	—
Sun Yat-sen University	0.454	0.642	0.706	drs	0.570	0.667	0.854	drs
South China University of Technology	0.679	0.852	0.778	—	1.000	1.000	1.000	—
Chongqing University	0.796	0.985	0.778	irs	1.000	1.000	1.000	—
Sichuan University	0.540	1.000	0.540	irs	0.699	1.000	0.699	drs
University of Electronic Science and Technology	1.000	1.000	1.000	—	1.000	1.000	1.000	—
Xi'an Jiaotong University	1.000	1.000	1.000	—	0.991	1.000	0.991	drs
NWAFU	0.875	0.967	0.943	drs	1.000	1.000	1.000	—
Lanzhou University	0.843	0.995	0.826	drs	1.000	1.000	1.000	—
Mean	0.838	0.910	0.902	—	0.927	0.967	0.960	—

Note: "drs" means diminishing returns to scale, "irs" means increasing returns to scale, and "-" means constant returns to scale.

(2) Pure technical efficiency analysis

Pure technical efficiency (PTE) is a decomposition index of comprehensive technical efficiency. It is a measure of production efficiency affected by factors such as management and technology. The closer its value is to 1, the higher the technical level and management ability of universities in intellectual property construction. It can be seen from Table 2 that the pure technical efficiency of intellectual property in China's 32 "double-first-class" universities in 2019 was 0.910, rising to 0.967 in 2020, showing an increasing trend, but it has not yet reached the effective state, and there is still a gap of 0.033. This reflects that China's "double first-class" universities still have room for improvement in the construction of intellectual property rights. In 2019, there are 13 institutions whose pure technical efficiency has reached the effective state. In 2020, it will rise to 24, accounting for 40.63% and 75% respectively. Among them, the pure technical efficiency of 12 universities such as Peking University, Tsinghua University, Northeastern University, Fudan University reached an effective state in both periods, indicating that their management and technical levels are relatively advanced.

From the absolute value in 2020, it can be seen that 24 universities including Peking University, Renmin University of China, and Tsinghua University have achieved effective pure technical efficiency of intellectual property operations

in "double first-class" universities. It shows that these universities have great advantages in intellectual property management and technology application, which has promoted a significant improvement in innovation capabilities. Eight universities, including China Agricultural University, Jilin University, and Tongji University, have not reached the effective status, mainly because these universities focus on the humanities and social sciences or have made achievements in a certain field, and their innovative development and technology applications are significantly lower than those of science and engineering universities. In addition, the construction of intellectual property rights is relatively comprehensive and practical, and these universities have insufficient technical capabilities and management experience, resulting in the inefficient use of input resources and unsatisfactory output effects. Therefore, in the follow-up development of such colleges and universities, they should constantly update their management concepts, learn from outstanding colleges and universities for management experience, strengthen technology applications, cultivate intellectual property talents, and enhance independent R&D and innovation and creativity capabilities.

(3) Scale efficiency analysis

Scale efficiency (SE) is another decomposition index of comprehensive technical efficiency, which is mainly affected by the size of the enterprise and the scope of business. The closer its value is to 1, the higher the scale efficiency, and the closer it is to the optimal scale. It can be seen from Table 2 that the scale efficiency of the intellectual property rights of China's 32 "double first-class" universities in 2019 was 0.902, and it rose to 0.960 in 2020. The growth rate is relatively fast, but it has not yet reached the optimal scale. There are 10 universities that have reached effective scale in 2019, and the number will increase to 19 in 2020, accounting for 31.25% and 59.38% respectively. Among them, seven universities, including Tsinghua University, Fudan University, and Southeast University, achieved effective scale and efficiency at two points in time, indicating that their investment in intellectual property has always been at the optimal scale.

Judging from the absolute value of 2020, there are 19 universities with effective IPR scale and efficiency, including Peking University, Renmin University of China, and Tsinghua University, reflecting the optimal allocation of input resources of these "double first-class" universities. In the future, the investment of R&D personnel and research funds should be maintained to ensure the maximum efficiency of scale. Among the 13 "double first-class" universities that have not reached the scale of effectiveness, the scale efficiency values of the 6 universities of China Agricultural University, Jilin University, East China Normal University, Zhejiang University, Hunan University, and Xi'an Jiaotong University are higher than average. The scale efficiency values of 7 universities including Beijing Normal University, Tianjin University and Dalian University of Technology are lower than the average level, and there is a lot of room for improvement in the future. Among them, the scale efficiency of 7 universities, including Tongji University, Shanghai Jiaotong University, and Zhejiang University, is lower than pure technical efficiency, indicating that scale efficiency is the main factor restricting their development. These universities should adjust the investment of R&D personnel and scientific research funds to improve overall technical efficiency. The two universities of China Agricultural University and East China Normal University have increasing returns to scale, indicating that these universities can increase investment appropriately to improve scale efficiency. The remaining universities that have not reached the effective state have diminishing returns to scale, and capital and personnel input should be planned rationally to reduce efficiency losses.

4.2 Dynamic analysis of Malmquist index

The Malmquist index can reflect the dynamic trend of efficiency. Therefore, based on the DEA model, this paper further analyzes the change process of the intellectual property operation performance of 32 "double first-class" universities in China. Through the dynamic changes of total factor productivity to analyze the development status of China's "double first-class" universities in terms of intellectual property construction and innovation and creation.

(1) Phase analysis of total factor productivity

Through the DEAP2.1 software, we can obtain the Malmquist index and its decomposition index of the intellectual property operation performance of China's "double first-class" colleges and universities in 2018-2020 (see Table 3).

Table 3: The Malmquist Index and Decomposition Index of Intellectual Property Rights of "Double First-Class" Universities in 2018-2020

Year	M	ECH	TCH	PECH	SECH
2018-2019	0.832	0.963	0.864	0.964	0.999
2019-2020	0.981	1.001	0.980	1.006	0.996
Mean	0.924	1.003	0.922	1.001	1.002

From 2018 to 2020, the total factor productivity M of intellectual property in 32 "double first-class" universities in China has not reached 1. It shows that the utilization rate of intellectual property in Chinese universities is not high, and the independent innovation ability and intellectual property construction are not perfect, and there is still a lot of room for

improvement in the future. On a yearly basis, total factor productivity is showing an increasing trend, indicating that the awareness of intellectual property protection in Chinese universities is gradually increasing, and the ability of scientific and technological innovation is increasing year by year. The change trend of total factor productivity M and technological progress TCH is roughly the same, indicating that the total factor productivity of intellectual property operation performance of China's "double first-class" universities is mainly affected by technological progress. That is to say, the improvement of intellectual property operation performance of China's "double first-class" colleges and universities is a technology-driven type. The technical efficiency index is greater than 1 in 2019-2020, with an average annual growth rate of 3%, which is on the rise as a whole, and has a positive driving effect on total factor productivity. In terms of decomposition indicators, pure technical efficiency has an average annual growth rate of 1%, and scale efficiency has an average annual growth rate of 2%. And in terms of changing trends, the trends of technical efficiency and scale efficiency are roughly the same, indicating that technical efficiency is mainly affected by scale. The annual growth rate of the Technological Progress Index is 3%, with the most obvious change and the highest growth rate. The main reason is that China currently focuses on technological development and implements the strategy of building a strong country through science and technology, which provides strong technical support for the construction of intellectual property rights.

(2) Regional analysis of total factor productivity

Table 4 shows the Malmquist Index of intellectual property innovation performance of 32 "Double First-Class" Universities in China and its breakdown indicators.

From 2018 to 2020, only six universities, including Renmin University of China and Shanghai Jiaotong University, have total factor productivity greater than 1, accounting for 18.75% of the total. It shows that the overall efficiency of the use of intellectual property in Chinese universities is not high. In the future, it is necessary to strengthen the construction of intellectual property and cultivate professional talents. In terms of growth drivers, the technical efficiency of 19 universities, including Peking University, Beijing Normal University, Nankai University, and Tianjin University, has reached an effective state. Their total factor productivity is less than 1, which is mainly restricted by the efficiency of technological progress. The technological progress indexes of Shanghai Jiaotong University and Huazhong University of Science and Technology have all decreased, but thanks to the substantial increase in technological efficiency, the growth of total factor productivity has been boosted. The technical efficiency and technological progress indexes of Renmin University of China, South China University of Technology, and Northwest A&F University are all greater than 1, indicating that the increase in total factor productivity of these three universities is jointly promoted by both.

It can be seen from the comprehensive technical efficiency change index that pure technical efficiency increased by 1% on average, and scale efficiency increased by 2% on average. In terms of changes in pure technical efficiency, East China Normal University, Huazhong University of Science and Technology and other 5 universities are greater than 1. Peking University, Renmin University of China, Tsinghua University and other 20 universities are equal to 1. China Agricultural University, Jilin University, Tongji University and other 7 universities are less than 1. Judging from the changes in the scale efficiency index, the scale efficiency index of universities such as Renmin University of China and China Agricultural University is greater than 1. Peking University, Beijing Normal University and other 16 universities are equal to 1. Tsinghua University, Jilin University and other 9 universities are less than 1. It shows that there is a big gap between universities in terms of technology application and intellectual property management, input and output efficiency needs to be improved, and resource allocation needs to be improved.

In order to further analyze the influence of regional factors on the performance of university intellectual property management, this paper divides the 32 "double first-class" universities into three types according to their location. On the whole, the total factor productivity of the eastern region is significantly greater than that of the central and western regions. The main reason lies in the large number of universities in the eastern region, a well-developed economy, sufficient research funding, abundant human resources, strong R&D capabilities and innovation motivation, and the ability to leverage independent advantages to optimize the allocation of resources. From the perspective of decomposition indicators, technical efficiency, pure technical efficiency and scale efficiency have reached the effective state, and only the efficiency of technological progress is less than 1. It shows that the failure of the central and western regions to reach an effective state is mainly constrained by technological progress. This also means that the central and western regions are biased towards economies of scale, while ignoring the improvement of technological level, and there is still room for improvement in technology application and intellectual property construction.

Table 4: Intellectual Property Malmquist Index and Decomposition Index of 32 "Double First-Class" Universities

University	M	ECH	TCH	PECH	SECH
Beijing University	0.864	1.000	0.864	1.000	1.000
Renmin University of China	1.082	1.077	1.004	1.000	1.077
Tsinghua University	0.959	0.969	0.990	1.000	0.969
China Agricultural University	0.965	0.999	0.966	0.993	1.006
Beijing Normal University	0.678	1.000	0.678	1.000	1.000
Nankai University	0.884	1.000	0.884	1.000	1.000
Tianjin University	0.83	1.000	0.830	1.000	1.000
Dalian University of Technology	0.972	1.000	0.972	1.000	1.000
Northeastern University	0.991	1.000	0.991	1.000	1.000
Jilin University	0.931	0.986	0.944	0.987	0.999
Fudan University	0.92	1.000	0.920	1.000	1.000
Tongji University	0.871	0.968	0.899	0.991	0.978
Shanghai Jiaotong University	1.014	1.089	0.931	1.000	1.089
East China Normal University	0.947	1.061	0.892	1.056	1.004
Nanjing University	0.956	0.979	0.976	0.982	0.997
Southeast University	0.96	1.000	0.960	1.000	1.000
Zhejiang University	0.971	1.000	0.970	1.000	1.000
Xiamen University	0.934	1.000	0.934	1.000	1.000
Shan Dong University	0.773	1.000	0.773	1.000	1.000
Ocean University of China	0.955	1.000	0.955	1.000	1.000
Wuhan University	0.941	0.995	0.945	0.999	0.997
Huazhong University of Science and Technology	1.039	1.075	0.966	1.028	1.045
Hunan University	0.726	0.883	0.822	0.884	0.999
Central South University	1.168	1.095	1.067	1.078	1.016
Sun Yat-sen University	0.997	1.013	0.984	1.054	0.962
South China University of Technology	1.016	1.000	1.016	1.000	1.000
Chongqing University	0.918	1.000	0.918	1.000	1.000
Sichuan University	0.858	0.929	0.924	1.000	0.929
University of Electronic Science and Technology	0.912	1.015	0.898	1.007	1.008
Xi'an Jiaotong University	0.853	0.975	0.875	0.978	0.996
NWAFU	1.036	1.000	1.036	1.000	1.000
Lanzhou University	0.825	1.000	0.825	1.000	1.000
East Region	1.018	1.000	1.018	1.000	1.000
Central Region	0.996	1.000	0.996	1.000	1.000
Western Region	0.963	1.000	0.963	1.000	1.000
Mean	0.924	1.003	0.922	1.001	1.002

5 Conclusions and Recommendations

Intellectual property construction is an important part of the development of universities and a key focus of national innovation and development. By constructing an input-output indicator system, this paper uses the DEA model and Malmquist index analysis method to measure the intellectual property operating performance of 32 "double first-class" universities in China from 2018 to 2020. The results found that the overall IP operational performance of China's 32 "double first-class" universities is on the rise, mainly due to the pull of technical efficiency, which shows that technology drives innovation and thus enhances the transformation of university IP achievements. However, the comprehensive technical efficiency and total factor productivity are both less than 1, which has not reached the effective state. It shows that China's "double first-class" universities still need to strengthen management and talent cultivation in terms of intellectual property construction, and increase investment in scientific research funds. From a regional perspective, there is a regional imbalance in total factor productivity, the highest in the eastern region, followed by the central region, and last in the western region, which may be related to economic development to a certain extent.

Based on the research conclusions, in order to further improve the intellectual property operation performance and scientific research innovation level of various universities, improve the incoordination of input and output, and improve the efficiency of scientific and technological achievements transformation, this article puts forward the following policy recommendations.

The first is to establish an intellectual property incentive mechanism to enhance the innovation and creativity of colleges and universities. On the one hand, universities need to improve the innovation environment, actively build intellectual property service centers, and earnestly exert their own innovation effects. At the same time, establish a sharing mechanism for patented inventions, improve the management mechanism by encouraging teacher guidance, student participation, university cooperation, and government support, improve the conversion rate of scientific research results, and form a large-scale and standardized development. On the other hand, colleges and universities should expand scientific research award standards according to their own development conditions. For example, science and engineering colleges and universities have strong scientific and technological innovation capabilities. Therefore, for such universities, not only must the paper achievements be included in the reward system, but also intellectual property achievements such as software development, data mining, and integrated circuits must be included in the reward standards. For comprehensive and social science colleges, they have strong advantages in copyright works and theoretical research, but they are obviously insufficient in patent inventions and patent applications. Therefore, it is necessary to focus on the investigation of theoretical research for such colleges and universities. Universities should design an evaluation system of intellectual property innovation achievements in line with their own development characteristics in accordance with their own conditions, so as to mobilize the enthusiasm of scientific researchers.

The second is to increase the input of talents and scientific research funds to improve the efficiency of resource utilization. On the one hand, a diversified and standardized talent management system is set up in accordance with the entire process of intellectual property management. Teachers and students are the main force in the creation of intellectual property rights in colleges and universities. They can understand the latest developments of the discipline in detail and continue to create scientific and technological achievements. Therefore, it is necessary to increase the cultivation of intellectual property creative talents. Intellectual property policy formulation, management planning, publicity and education require specific management talents. Therefore, colleges and universities should introduce professional intellectual property management talents, regularly cooperate with external institutions, organize overseas training, and improve the construction of intellectual property administrative management talents. On the other hand, colleges and universities still need to increase funding, by setting up a reasonable intellectual property transformation platform, conducting extensive market research, in-depth investigation of the use of funds, comprehensively evaluating project development prospects and market value, and strengthening the effective allocation of scientific research funding.

The third is to rationally allocate scientific research resources and promote the balanced development of the east and the west. It can be seen from the existing research that the efficiency of intellectual property innovation in universities in the central and western regions is significantly lower than that in the eastern developed regions. As an important manifestation of cultural soft power, intellectual property plays an important role in regional development and the implementation of the national cultural power strategy. Therefore, it is necessary for the country to increase its policy inclination and attach great importance to the current regional imbalance. By increasing financial support, experts are selected to regularly guide the areas where the development of intellectual property is weak, guide scientific research talents and funds to flow to the central and western regions where education is lacking, and promote the balanced development of intellectual property innovation performance between regions. Local governments should also raise awareness of intellectual property protection, formulate long-term plans, improve the linkage mechanism between local industries and scientific research results of universities, and rely on local industrial resources to promote a high degree of integration of production, education and research. Universities in the central and western regions should hold regular exchanges and cooperation, increase the intensity of talent introduction, continue to give play to their own advantages on the basis of making up for their shortcomings, and ensure that the efficiency of scientific research and innovation is steadily improved.

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