Evaluation of scientific research innovation efficiency of "Double First-Class Universities——Based on DEA-Malmquist model

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Abstract: Using DEA-Malmquist model, this paper evaluates the scientific research and innovation efficiency of Double First-Class Universities in China from 2009 to 2017. The results show that there is still room for improvement in the comprehensive technical efficiency of the National Double First-Class Universities from 2009 to 2017, and the average number of universities with increasing scale efficiency basically reaches 1/4 of the total number of universities. The fluctuation of comprehensive technical efficiency, technical progress and total factor productivity is relatively large, and it is not stable on the whole.

1. Introduction

The state promotes the "double first-class" construction strategy and puts forward higher requirements for "double first-class" colleges and universities. The national "double first-class" strategy not only retains the advantages of the original 985 and 211 Project universities, but also forms a refined development for some universities with school running characteristics and vigorously develops advantageous disciplines. [1][2]

Domestic and foreign scholars have conducted relevant research on the evaluation of scientific research innovation efficiency in Colleges and universities. Dongping [3] thinks that the technical efficiency and scale efficiency of some colleges and universities in China need to be improved to a certain extent, but the overall scientific research efficiency level of colleges and universities is good. Zhang et al. [4] compared the scientific research efficiency of various colleges and universities, and put forward reasonable suggestions.

With the continuous enhancement of China's economic strength and the increasing investment of scientific research funds in Colleges and universities, the problem to be solved for colleges and universities is how to improve the use efficiency. Based on this, this paper mainly uses DEA Malmquist model to evaluate the scientific research innovation efficiency of 40 double first-class universities in China from 2009 to 2017.

2. Model construction

2.1 DEA-BCC model

DEA is a nonparametric method used to evaluate input-output efficiency and is suitable for multi output multi input comprehensive evaluatio n method. BCC model changes the constant return to scale assumption of CCR model into variable return to scale.

In this paper, DEA-BCC model is used to analyze the scientific research innovation efficiency of colleges and universities. The model is as follows:

Assuming that the number of universities is s. Each university has m inputs and n outputs, X_j and Y_j which means input variables and output variab les. Namely:

$$X_j = (x_{1j} \quad x_{2j} \quad \dots \quad x_{mj})^T$$

$$x_{ij} > 0, \; i=1, 2, ..., m; \; j=1, 2, ..., s.$$

$$Y_j = (y_{1j} \quad y_{2j} \quad \ldots \quad y_{nj})^T$$

$$y_{rj} > 0, \; r = 1, 2, \ldots, n; \; j = 1, 2, \ldots, s.$$

After introducing the non Archimedean infinitesimal parameter, the model is:

$$\min \left[\theta - \varepsilon \left(e^T s^- + e^{\wedge T} s^+\right)\right]$$

$$s.t. \begin{cases} \sum_{j=1}^{s} \lambda_j x_j + s^+ = \theta X_p \\ \sum_{j=1}^{s} \lambda_j y_j - s^- = Y_p \\ \lambda_j \geq 0, \quad j = 1, 2, \ldots, s \\ \sum_{j=1}^{s} \lambda_j = 1 \\ s^+ \geq 0, \; s^- \geq 0 \end{cases}$$

(1) When $\theta^* = 1$, and $s^{*+} = 0$, $s^{*-} = 0$, the DMU is DEA efficient;

(2) When $\theta^* = 1$, the DMU is weak DEA effective;

(3) When $\theta^* < 1$, the DMU was not DEA effective.

2.2 DEA-Malmquist index

Malmquist index is mainly used to measure the total factor productivity of decision-making units, which can be divided into effch and techch. Therefore, Malmquist index is used to analyze the technological change and efficiency change.

$$TC = \sqrt{\frac{E^t(x^t, y^t)}{E^{t+1}(x^t, y^t)}} \sqrt{\frac{E^t(x^{t+1}, y^{t+1})}{E^{t+1}(x^{t+1}, y^{t+1})}} \qquad EC = \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)}$$

$$Tfpch = EC * TC = \sqrt{\frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)}} \sqrt{\frac{E^t(x^{t+1}, y^{t+1})}{E^{t+1}(x^t, y^t)}}$$

According to the optimal solution obtained by the model, the following conclusions can be drawn:

(1) If $Tfpch = 1$, it indicates that the productivity level is not changed;

(2) If $Tfpch > 1$, it indicates that the productivity level is increased;

(3) If $Tfpch < 1$, it indicates a decline in productivity.

2.3 Selection of evaluation indicators and data sources

In constructing the evaluation index system of scientific research innovation efficiency of double first-class universities, because the evaluation method of DEA requires that the input and output indexes must be clear and quantifiable, this paper selects the input and output indexes that can be quantified. [5][6] among the input indicators, science and technology funds (1000 yuan) and teaching and scientific research personnel (people) are selected. In the output indicators, the number of achievements awarded (items), the number of monographs published (departments), the total number of scientific and technological topics (items) and the number of academic papers published (articles) are selected.

Considering the availability of data, 40 Double First-Class Universities in China are selected as the decision-making unit to calculate the scientific research and innovation efficiency of Double First-Class Universities in 2009-2017.

3. Static evaluation of scientific research innovation efficiency in Colleges and Universities Based on DEA-BCC model

Based on the collected data, Deap2.1 software is used to statically evaluate the scientific research and innovation efficiency of 40 double first-class universities in China from 2009 to 2017.Table 1 analyzes the overall scientific research innovation efficiency of double first-class universities from 2009 to 2017.

Table 1 overall analysis of scientific research innovation efficiency of double first-class universities from 2009 to 2017

DEA efficiency	Efficiency value characteristics	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Effch	Average	0.771	0.821	0.831	0.811	0.811	0.845	0.841	0.842	0.853	0.825
	TE = 1 number of colleges and Universities	10	15	15	14	12	13	14	14	15	-
Pech	Average	0.842	0.894	0.905	0.870	0.901	0.917	0.916	0.895	0.907	0.894
	PTE = 1 number of Universities	18	21	22	19	19	21	23	20	19	-
Sech	Average	0.919	0.916	0.921	0.933	0.899	0.923	0.919	0.941	0.941	0.924
	SE = 1 number of colleges and Universities	10	15	16	15	12	13	15	16	15	-
Returns to scale	Decreasing number of colleges and Universities	19	19	20	19	18	15	16	15	13	17
	Increasing number of colleges and Universities	11	6	4	6	10	12	9	9	10	9
	Constant number of colleges and Universities	10	15	16	15	12	13	15	16	17	14

It can be seen from table 3.2 that there is still much room for improvement in the overall level of scientific research efficiency of national double first-class universities from 2009 to 2017. The average value of comprehensive technical efficiency is 0.825, and the average number of colleges and universities with increasing economies of scale basically reaches 1 / 4 of the total number of colleges and universities. The results of analysis from different dimensions show that:

(1) From the perspective of time, from 2009 to 2017, there were about 14 universities in the best scale and optimal state every year, indicating that the input and output were basically consistent; However, the number of colleges and universities with increasing returns to scale basically reaches 1 / 4.

(2) From the perspective of efficiency, the average value of comprehensive technical efficiency from 2009 to 2017 is 0.825. Therefore, in terms of comprehensive technical efficiency, the average comprehensive technical efficiency of national double first-class universities from 2009 to 2017 is not high, and there is still some room for improvement. Among them, the comprehensive technical efficiency of Nankai University, Northwest University of agriculture is low, and there is still much room for improvement. In addition, the average value of pure technical efficiency is lower than the average value of scale efficiency, which also shows that there is a certain room for improvement in pure technical efficiency, indicating that resources have not been reasonably allocated. Therefore, we should further improve the scientific research management and optimize the input-output structure, so as to further improve the technical level.

(3) From the analysis of returns to scale, the average number of universities with decreasing returns to scale of scientific research in national double first-class universities is 17, the average number of universities with increasing returns to scale is 9, and the average number of universities with constant returns to scale is 14. Among them, the scale income of universities such as Beijing University of technology, China Agricultural University and Hunan University is increasing, and the allocation efficiency of resource input and output needs to be further improved.

4. Dynamic evaluation of scientific research and innovation efficiency based on Malmquist index

Malmquist index is used to evaluate the scientific research innovation efficiency of national double first-class universities from 2009 to 2017. Table 4.1 and 4.2 analyzes the scientific research efficiency in different universities and years; The dynamic analysis of development is carried out in Figure 1.

4.1 analysis of scientific research innovation efficiency in different universities

Table 2 analyzes the scientific research innovation efficiency of different universities, and shows the average Malmquist index and its decomposition of double first-class universities from 2009 to 2017.

Table 2 average Malmquist index and decomposition of double first-class universities from 2009 to 2017

University name	Effch	Techch	Pech	Sech	Tfpch
Peking University	1.074	0.940	0.983	1.093	1.010
Tsinghua University	0.983	0.955	1.000	0.983	0.938
Renmin University of China	1.000	0.819	1.000	1.000	0.819
Beijing University of Aeronautics and Astronautics	1.000	1.027	1.000	1.000	1.027
Beijing University of Technology	1.061	0.962	1.060	1.001	1.021
China Agricultural University	1.001	0.998	1.000	1.001	0.999
Beijing Normal University	1.000	0.984	1.000	1.000	0.984
Nankai University	1.059	0.952	1.063	0.996	1.008
Tianjin University	1.023	0.974	1.022	1.000	0.996
Dalian University of Technology	1.047	1.004	1.046	1.002	1.052
Jilin University	0.993	0.918	0.980	1.013	0.911
Harbin Institute of Technology	1.046	0.963	1.044	1.002	1.007
Fudan University	1.021	0.963	1.032	0.989	0.984
Tongji University	0.974	0.980	0.977	0.996	0.954
Shanghai Jiaotong University	1.016	0.935	1.000	1.016	0.950
East China Normal University	1.037	0.977	1.040	0.997	1.012
Nanjing University	1.018	0.986	1.018	1.000	1.003
Southeast University	1.023	0.980	1.016	1.007	1.003
Zhejiang University	0.964	0.957	1.000	0.964	0.923
University of science and technology of China	0.998	1.001	0.998	1.000	0.999

Xiamen University	0.976	0.975	0.973	1.003	0.951
Shandong University	0.968	0.927	0.976	0.992	0.897
Ocean University of China	1.019	0.948	1.014	1.006	0.967
WuHan University	1.019	0.942	1.014	1.005	0.960
Huazhong University of science and technology	0.957	0.954	0.979	0.978	0.913
Central South University	1.067	0.979	1.024	1.042	1.044
Sun Yat-sen University	1.048	0.887	1.000	1.048	0.930
South China University of Technology	1.000	0.981	1.000	1.000	0.981
Sichuan University	1.042	0.952	1.017	1.025	0.993
University of Electronic Science and technology	0.976	0.935	0.980	0.996	0.913
Chongqing University	1.033	0.963	1.031	1.002	0.995
Xi'an Jiaotong University	1.060	0.952	1.063	0.998	1.009
Northwest University of Technology	0.998	0.998	0.998	1.000	0.996
Lanzhou University	0.988	0.925	0.991	0.997	0.914
Northeastern University	1.064	0.999	1.061	1.003	1.063
Zhengzhou University	1.001	0.955	1.000	1.001	0.956
Hunan University	1.009	0.941	1.009	1.000	0.949
Yunnan University	0.972	0.974	0.972	0.999	0.946
Northwest University of agriculture and forestry science and technology	1.091	0.958	1.081	1.009	1.045
Xinjiang University	1.000	0.924	1.000	1.000	0.924
Average	1.015	0.958	1.011	1.004	0.972

From 2009 to 2017, the average total factor productivity, scale efficiency and technological progress rate of Double First-Class Universities in China are 0.972, 1.004 and 0.958 respectively. From the specific value, the total factor productivity of 17 universities such as Renmin University of China, Jilin University and Shanghai Jiao Tong University is lower than the average. From the total factor productivity, we can see that there is still room to improve the scientific research performance level.

4.2 analysis of scientific research and innovation efficiency of universities in different years

Table 3 shows the average annual Malmquist index and decomposition from 2009 to 2017. The results are as follows:

Table 3 average annual Malmquist index and breakdown from 2009 to 2017

Year	Effch	Techch	Pech	Sech	Tfpch
2009-2010	1.070	0.880	1.069	1.001	0.942
2010-2011	1.017	0.918	1.011	1.005	0.933
2011-2012	0.976	1.001	0.962	1.015	0.977
2012-2013	0.999	0.944	1.041	0.959	0.942
2013-2014	1.054	0.964	1.021	1.033	1.016
2014-2015	0.990	1.061	0.997	0.993	1.051
2015-2016	1.003	0.949	0.975	1.028	0.952
2016-2017	1.016	0.956	1.017	0.999	0.972
Average	1.015	0.958	1.011	1.004	0.972

From the perspective of total factor productivity (tfpch), during 2009-2017, the average value is 0.972, showing a fluctuating upward trend. In 2009-2011, total factor productivity decreased to a certain extent, with a decline rate of 1%; in 2011-2012, total factor productivity increased from 0.933 to 0.977, with a growth rate of 4.5%. From 2012 to 2013, TFP decreased to 0.942, with a decrease rate of 3.6%. In 2013-2015, total factor productivity increased significantly, with a growth rate of 10.4%; in 2015-2016, total factor productivity decreased to 0.952, with a decline rate of 9.4%; in 2016-2017, total factor productivity increased to 0.972, with a growth rate of 2.1%. Therefore, on the whole, the overall level of TFP shows a fluctuating upward trend.

Accordig effch, the average value is 1.015, showing a downward trend. In 2009-2012, the decline rate of comprehensive technical efficiency is 8.8%, which is due to the decline of pure technical efficiency. During 2012-2013, the comprehensive technical efficiency improved from 0.976 to 0.999, with a growth rate of 2.3%, mainly due to the improvement of pure technical efficiency. From 2013 to 2014, the comprehensive technical efficiency continued to rise, from 0.999 to 1.054, with a growth rate of 5.2%. During 2014-2015, the comprehensive technical efficiency decreased to 0.99, with a decline rate of 6.1%. In 2015-2016, the comprehensive technical efficiency increased to 1.003, mainly due to the improvement of scale efficiency. In 2016-2017, the comprehensive technical efficiency increased to 1.016, mainly due to the increase of pure technical efficiency. Therefore, in general, the overall level of comprehensive technical efficiency showed a downward trend from 2009 to 2017.

From the perspective of technological progress efficiency, from 2009 to 2017, the average efficiency of technological progress is 0.958, showing an overall upward trend. From 2009 to 2012, the efficiency of technological progress showed a significant upward trend, with a growth rate of 12%; however, there was a certain decline from 2012 to 2013, from 1.001 to 0.944, with a decline rate of 5.7%. In 2013-2015, technological progress increased to 1.061, with an increase rate of 11%. However, during 2015-2016, there was a significant decline, with a decline rate of 10.6%. In 2016-2017, it rose to a certain extent, from 0.949 to 0.956, with a growth rate of 0.7%. In general, the overall level of technological progress showed an upward trend from 2009 to 2017.

4.3 development trend analysis

Figure 1 shows the change trend of comprehensive technical efficiency, technological progress and total factor productivity from 2009 to 2017. The results are as follows:

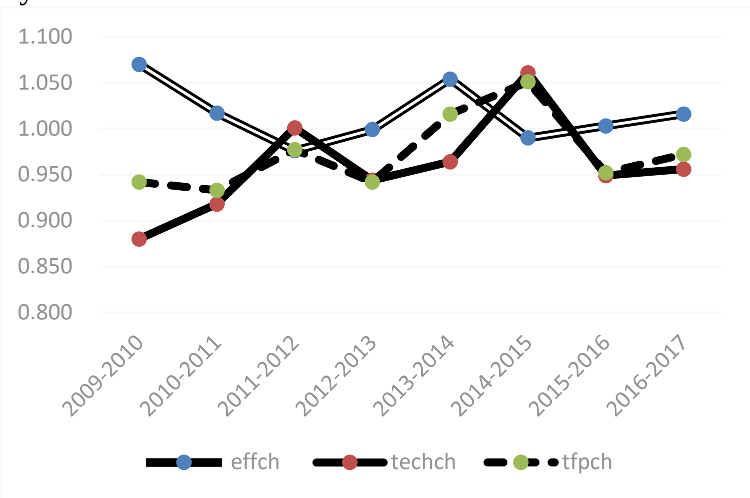

Figure 1 Malmquist index and breakdown of average annual from 2009 to 2017

From 2009 to 2017, the overall technical efficiency of China's double first-class universities showed a downward trend, and the overall technological progress and total factor productivity showed an upward trend. It can be seen from the figure that the change trend is basically the same as that of total factor productivity, but the change range of technological progress rate is larger, which shows that technological progress plays a more important role in the scientific research performance. In order to improve the total factor productivity of double first-class colleges and universities, we should pay more attention to the technological progress rate.

5. Conclusions

The following conclusions can be drawn: In 2009-2017, there is still room for improvement in the scientific research performance level; the comprehensive technical efficiency, technical progress and total factor productivity show a certain upward and downward trend, which is not stable on the whole.

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