ISSN: 2688-8653

Evaluation of Input-output Efficiency of Higher Education in China

-- Based on Three-stage and Super-efficiency DEA Model

Wenxuan Liu[1, a], Luyu Xie[2, b]

[1]Department of Electrical and Information Engineering, Shandong University of Science and Technology, 250000, China

[2]Department of Finance, Qilu University of Technology, 250000, China

[a]553858245@qq.com, [b]jieluyu2011@163.com

Abstract

Based on systematic thinking, this paper establishes an evaluation index system, and introduces Three-stage DEA and Super-efficiency DEA models to evaluate the efficiency of Chinese higher education. The research shows that the environmental system has a significant impact on the efficiency of higher education; In the case of stripping off the external environment and random factors, the technical efficiency of higher education in various provinces and cities has changed significantly; After adjustment, the average comprehensive technical efficiency, pure technical efficiency and scale efficiency of national higher education are all above 0.90, and the overall level is high; The main factor affecting the comprehensive technical efficiency of higher education is scale efficiency. There are 13 provinces and cities in China at the forefront of higher education technical efficiency, but the Super-efficiency DEA value of higher education input and output is obviously different. Therefore, various regions should tap the potential of improving the efficiency of higher education through management innovation, optimizing the allocation of educational resources and improving the external environment.

Keywords

Higher Education; Three-stage DEA Model; Super-efficiency DEA Model; Technical Efficiency.

1. Introduction

From the perspective of systematic thinking, higher education is an organic system with interrelated development and change in many aspects. Systematic thinking can greatly simplify the cognition of higher education and bring about a holistic view and a global view. Based on the gross enrollment rate of the school-age population in higher education, Professor Trow divides higher education into three stages: elitism (the gross enrollment rate of higher education is below 38%), popularization (the gross enrollment rate is between 38% and 80%) and popularization (the gross enrollment rate is over 80%) [3]. In 2039, the gross enrollment rate of higher education in China has reached 0-93%, and the total number of students in various types of higher education has reached 30,000-330,000. However, the growth of education scale does not represent the inevitable improvement of education quality, and there are still some problems in higher education, such as insufficient supply, weak innovation, failure of resource allocation and low efficiency [2]. At present, China's higher education has entered a critical period of promoting the construction of world-class universities and first-

ISSN: 2688-8653

class disciplines as a whole, which inevitably requires China's higher education to take the connotative development path with quality improvement as the core. Based on systematic thinking, this paper establishes an evaluation index system from the perspective of input and output of China's higher education from the perspective of holistic view and global view, and introduces Three-stage DEA and Super-efficiency DEA models to evaluate the efficiency of China's higher education.

According to the existing research, The evaluation methods of input-output efficiency of higher education mainly include statistical regression analysis [3], index analysis, analytic hierarchy process [8] and data envelopment analysis [4], DEA (Data Envelopment Analysis) is suitable for the efficiency evaluation of complex systems with multi-input and multi-output, and can measure the relative efficiency of each production decision-making unit because of its advantages such as no need to determine the function form in advance, no need to assign weights to indexes and unified dimensions. At present, DEA research can be divided into two situations according to different production decision-making units: (3) Taking regions as production decision-making units, this paper examines the operational efficiency of higher education institutions in different countries or regions, for example, JEAN-PASCAL G et al [7] studies the efficiency of university education systems in urban and rural areas of the United States; ARIETOVNIK A [8] uses DEA to analyze the effectiveness of ICT education in 27 EU member countries and OECD countries; (2) Taking universities as production decision-making units, for example, Duan Xiaomei [9] applies Super-efficiency DEA model to measure the scientific research performance of national universities, and SAHNEY S et al [10] combines DEA method and AHP method to evaluate the academic efficiency, teaching efficiency and consulting efficiency of Indian universities.

At present, many researches have obtained very valuable results, which provide a good research foundation for this paper. However, the research on the input-output efficiency of higher education is still limited to the traditional DEA analysis, lacking in considering the influence of environmental system and random factors, and having the defect that the influence of environmental and error factors on efficiency cannot be stripped away. Therefore, from the perspective of system science, this paper adopts "Three-stage DEA model" to scientifically evaluate the efficiency of China's higher education, which can not only eliminate the environmental factors and random errors affecting the efficiency, but also introduce Super-efficiency DEA model to further distinguish multiple simultaneous effective production decision-making units, in order to draw more accurate conclusions.

2. Research Design and Data

Higher education is a dynamic and complex system with multi-factor input and multi-output. Analyzing from the perspective of input and output is conducive to grasping the common attributes and laws of higher education as a whole. The input of higher education mainly includes the input of manpower, financial resources and material resources, and the output includes the output of personnel training, scientific research achievements and social services. Combined with the characteristics of higher education system, the input-output index system is constructed. Environmental variables use SIMAR L et al [11] for reference to select factors that have an impact on input-output efficiency, but are not in the subjective controllable range of samples. The main environmental variables of higher education include: macroeconomic environment (economic development level, residents' income level and urbanization level), government policy support for higher education development (the proportion of education expenditure to fiscal expenditure) and education expenditure structure (the proportion of primary and secondary education expenditure to education expenditure). Input and output index data This paper adopts the statistical yearbooks published by the state in 2016, including

ISSN: 2688-8653

China Education Statistical Yearbook, China Education Expenditure Statistical Yearbook, Compilation of Science and Technology Statistics of Colleges and Universities, China Labor Statistical Yearbook and China Statistical Yearbook. From the perspective of integrity and synergy of complex systems, the index system of higher education input and output is shown in Table 1.

Table 1. Input-output index system of higher education

Indicator type	First-class index	Secondary index	Unit
Input index	Human resources	Number of full-time teachers X1	People
	Financial resources	Investment in education funds X.	Ten thousand
		Investment in scientific research funds X3	Ten thousand
	Material resources	Year-end fixed assets value of colleges and	Ten thousand
Output indicators	Talent training	Number of graduates from institutions of	People
	Scientific research	Total number of scientific papers and works	Articles
	Scientific research	Number of acceptance of national projects "3	Items
	Social services	Total employed population with higher	People

3. Empirical Analysis

3.1. Empirical Results of Traditional DEA in the First Stage

Running DEAP2.1 software, based on input-oriented BCC model, the results are shown in Table 2. The comprehensive technical efficiency value of higher education in 16 provinces and cities has not reached 1, showing different degrees of inefficiency, and there is room for improvement in pure technical efficiency or scale efficiency; And the other 16 provinces and cities of comprehensive technical efficiency, pure technical efficiency and scale efficiency are all 1, in the forefront of technical efficiency. In terms of returns to scale, the returns to scale of 11 provinces and cities are in an increasing stage, while those of 4 provinces and cities are in a decreasing stage, while those of other provinces and cities remain unchanged.

Table 2. Efficiency level and scale income of the first stage higher education in 31 provinces and cities of China

Region	Comprehensiv	Pure	Scale	Return	Region	Comprehensiv	Pure	Scale	Return
Beijing	0.270	1.200	0.279	Drs	Hubei	0.979	1.200	0.779	Drs
Tianjin	0.220	0.929	0.921	Irs	Hunan	1.200	1.200	1.200	-
Hebei	1.200	1.200	1.200	-	Guangdon	1.200	1.200	1.200	-
Shanxi	1.200	1.200	1.200	-	Guangxi	1.200	1.200	1.200	-
Inner Mongolia	1.200	1.200	1.200	-	Hainan	0.944	0.994	0.949	Irs
Liaoning	0.203	0.905	0.997	Irs	Chongqing	0.939	0.943	0.979	Irs
Jilin	1.200	1.200	1.200	-	Sichuan	1.200	1.200	1.200	-
Heilongjian	1.200	1.200	1.200	-	Guizhou	0.991	0.09	0.972	Irs
Shanghai	1.200	1.200	1.200	-	Yunnan	0.941	0.949	0.974	Irs
Jiangsu	1.200	1.200	1.200	-	Tibet	0.927	1.200	0.927	Irs
Zhejiang	1.200	1.200	1.200	-	Shaanxi	0.999	0.971	0.999	Drs
Anhui	1.200	1.200	1.200	-	Gansu	0.962	0.969	0.979	Irs
Fujian	0.876	0.779	0.999	Irs	Qinghai	1.200	1.200	1.200	-
Jiangxi	0.939	0.959	0.980	Irs	Ningxia	0.949	1.200	0.949	Irs
Shandong	0.943	1.200	0.943	Drs	Xinjiang	1.200	1.200	1.200	-
Henan	1.200	1.200	1.200	-	Average	0.966	0.980	0.929	

ISSN: 2688-8653

3.2. SFA Regression Results in the Second Stage

Table 3. SFA regression results

Project	Relaxation variable of full-time teachers	Relaxation variable of educational expenditure investment	Slack variable of investment in science and technology funds	Relaxation variable of fixed assets value in colleges and universities at the end of
Constant term	-10346.664***	-133596.420***	-13901.977***	-2276353.600***
	(-10346.779)	(-7649.431)	(-7532.793)	(-2276353.900)
Real per capita GDP growth rate/%	153.935***	13703.335***	-3373.967***	110433.380***
	(143.256)	(66.977)	(-20.973)	(112433.930)
Per capita disposable income of residents/yuan	-0.306**	-7.423***	-0.554	-35.727***
	(-2.472)	(-3.440)	(-0.372)	(-315.965)
Urbanization rate/%	123.671***	2904.443**	660.470*	20334.163***
	(122.666)	(2.173)	(1.975)	(29333.973)
Proportion of education expenditure to fiscal expenditure/%	134.466***	4427.992***	-342.221***	22389.533***
	(132.971)	(73.356)	(-10.613)	(22389.314)
Proportion of primary and secondary education funds to education funds/%	39.094***	-1052.912	233.315	133.931***
	(29.647)	(-1.466)	(1.952)	(133.961)
Sigma-squared	1.762E+07***	1.905E+10***	1.431E+00***	4.917E+11***
	(1.762 E +07)	(7605E +17)	(1.431 E +09)	(4.617 E +11)
Gamma	1.400***	0.905***	0.936***	1.400***
	(56617.309)	(136.154)	(9.595)	(3634262300)
LoplikelihooP	-277.938	-337.921	-349.597	-436.103
LRtestPtheone-sidederroe	23.951	13.436	15.091	10.405

Note: *, **, *** are significant at the level of 10%,%, 1%, respectively, and the values in brackets are the corresponding t statistical values.

Higher education system is a complex system composed of interrelation and interaction. Using SFA model, this paper studies the influence of management factors, external environment factors and random factors on each input relaxation variable. Frontier 4.9 software is used to estimate SFA model. The regression results are shown in Table 3. (1) When GDP per capita increases, it is beneficial to reduce the redundancy of scientific research funds and have a positive impact on educational efficiency; However, it will lead to redundancy in the number of full-time teachers, investment in education funds and fixed assets of colleges and universities at the end of the year, which will have an adverse impact on the efficiency of higher education as a whole. This is reflected in some developed areas, where the investment resources in higher education are abundant, but the problem of "big but not strong" is more prominent, resulting in low innovation efficiency. Therefore, it is necessary not only to expand the investment in higher education resources, but also to effectively integrate resources such as the number, quality level and fixed assets facilities of teachers, optimize the allocation of higher education resources, and improve educational efficiency. (2) The increase of per capita disposable income is conducive to reducing the number of full-time teachers and the redundancy of education funds, enhancing the enthusiasm of university teachers, promoting the effective use of these resources, and thus improving technical efficiency. (3) With the increase of urbanization rate, urbanization brings about the increase of higher education demand and the expansion of enrollment scale, which leads to the redundancy of science and technology expenditure, education expenditure, the number of full-time teachers and the investment of fixed assets at the end of the year. However, it does not mean that the output efficiency of higher education should be improved. It is necessary to further improve the level and quality of running schools, create an environment for the transformation of scientific research and teaching achievements,

ISSN: 2688-8653

and optimize the efficiency of internal resource allocation in colleges and universities. (4) The increase of fiscal expenditure on education will increase the expenditure on scientific research in this area, However, if there is no reasonable structural allocation of university resources, there are some problems in educational work, such as emphasizing investment, neglecting management and neglecting performance, which will hinder the improvement of higher education efficiency, which means that universities need to spend more time, energy and resources on connotation construction. (5) The increase of the proportion of primary and secondary education funds means the decrease of the proportion of higher education funds, which can be regarded as the decrease of the investment of higher education financial resources, which hinders the improvement of higher education efficiency to a certain extent.

3.3. Empirical Results of DEA after Input Adjustment in the Third Stage

Table 4. Efficiency level and scale income of the third stage higher education in 31 provinces and cities of China

Region	Comprehensive	Pure	Scale	Returns	Region	Comprehensive	Pure	Scale	Returns
Beijing	0.926	1.200	0.996	Drs	Hubei	1.200	1.200	1.200	-
Tianjin	0.962	1.200	0.762	Irs	Hunan	1.200	1.200	1.200	-
Hebei	1.200	1.200	1.200	-	Guangdong	1.200	1.200	1.200	-
Shanxi	1.200	1.200	1.200	-	Guangxi	1.200	1.200	1.200	-
Inner Mongolia	1.200	1.200	1.200	-	Hainan	0.944	1.200	0.744	Irs
Liaoning	0.776	0.901	0.979	Irs	Chongqing	0.933	0.959	0.979	Irs
Jilin	0.921	1.200	0.991	Irs	Sichuan	1.200	1.200	1.200	-
Heilongjiang	1.200	1.200	1.200	-	Guizhou	0.978	0.674	0.766	Irs
Shanghai	1.200	1.200	1.200	-	Yunnan	0.907	0.971	0.936	Irs
Jiangsu	1.200	1.200	1.200	-	Tibet	0.493	1.200	0.697	Irs
Zhejiang	1.200	1.200	1.200	-	Shaanxi	0.971	0.971	1.200	-
Anhui	1.200	1.200	1.200	-	Gansu	0.679	0.942	0.933	Irs
Fujian	0224	0.903	0.979	Irs	Qinghai	0.279	1.200	0.279	Irs
Jiangxi	0.746	0.976	0.955	Irs	Ningxia	0.997	1.200	0.997	Irs
Shandong	0.956	1.200	0.759	Drs	Xinjiang	1.200	1.200	1.200	-
Henan	1.200	1.200	1.200	-	Average	0.919	0.999	0.931	

Note: Comprehensive technical efficiency = pure technical efficiency * scale efficiency; "R, 4rs,-" means increasing returns to scale, decreasing returns to scale and unchanged returns to scale respectively.

Environmental system has great restriction and influence on the development of higher education. If the restriction of environment is ignored, it may seriously affect the implementation of higher education decision-making. In view of the external economic environment and the influence of random factors in each province and city, in order to investigate the real efficiency level, the adjusted input variable replaces the initial input variable in the first stage, and the output data remains unchanged. DEAP2.3 software is used to calculate the input-oriented BCC model again. The results are shown in Table 4. The provinces and cities at the forefront of higher education technical efficiency decreased from-to 15; Jilin and Qinghai, where DEA is effective in middle and higher education, become technical ineffective units after adjustment, which is due to the decline of scale efficiency value; However, Hubei Province, which originally belonged to technical ineffectiveness, rose to the forefront of technical efficiency of higher education in the third stage, and its efficiency improvement benefited from the increase of scale efficiency after adjustment. Before and after the adjustment, the scale income of higher education in Hubei and Shaanxi changed from decreasing state to unchanged state, Jilin and Qinghai changed from effective scale to increasing scale income, and

ISSN: 2688-8653

the scale status of other provinces and cities did not change. The average value of comprehensive technical efficiency of higher education in China decreased from 0.966 to 0.9907, the average value of pure technical efficiency increased from 0.99-0 to 0.99-8, and the average value of scale efficiency decreased from 0.2499 to 0.2431. On the whole, the inhibitory effect of regulation rate model efficiency on comprehensive technical efficiency was greater than that of pure technical efficiency. Most provinces and cities have mature management ability in higher education, and the scale of higher education operation is also suitable.

Hainan, Tibet, Qinghai, Ningxia, Jilin, Shandong and Beijing should focus on improving scale and efficiency. The scale of higher education in Beijing and Shandong is relatively large, but it is difficult to coordinate all aspects of higher education effectively, which leads to the decline of efficiency. Hainan, Tibet, Qinghai, Ningxia and Jilin are in the increasing stage of educational scale income, so we can increase investment in higher education, especially Tibet and Qinghai should focus on expanding the scale of higher education and realizing the optimal allocation of resources. Among them, the scale of higher education in Guizhou, Yunnan, Gansu and Jiangxi is inefficient, so we should appropriately increase factor input to improve scale efficiency and pay attention to rational allocation of factors; There is still much room for improvement in the management level of higher education in Fujian, Liaoning and Chongqing.

3.4. Empirical Results of Super-efficiency DEA

In order to evaluate the effectiveness of higher education in 19 provinces and cities, it is necessary to analyze the Super-efficiency DEA model of these 19 provinces and cities, and the results are shown in Table 5 by using EMS1.9 software. No matter how much investment in Heilongjiang, Shanghai, Jiangsu and Guangdong increases, the production decision-making unit will remain effective. Heilongjiang is a province with a large scale of higher education, which has built a higher education system with Heilongjiang characteristics. It is a province with strong regional competitiveness of higher education, and its Super-efficiency value is also in the forefront of the whole country. The Super-efficiency value of Henan is 12,999, which shows that Henan is still at the forefront of higher education technical efficiency after increasing 99.29% of higher education investment on the existing basis. By the same token, Hubei, Anhui, Hebei, Hunan and Sichuan still have DEA validity after increasing the existing input-output scale by 229%, 926%, 921%, 920% and 920% respectively.

Table 5. Super-efficiency values of provinces and cities with DEA effective input-output of higher education in China

Region	Super efficiency value	Rank	Region	Super efficiency value	Rank	Region	Super efficiency value	-Ranking
Shanghai	Big	1	Xinjiang	1.743	3	Sichuan	1.280	9
Jiangsu	Big	1	Inner Mongolia	1.699	4	Hunan	1.279	7
Guangdong	Big	1	Zhejiang	1.234	9	Hebei	1.291	10
Heilongjiang	Bir	1	Guangxi	1.197	6	Anhui	1.046	11
Henan	1.759	2	Shanxi	1.080	9	Hubei	1.025	12

4. Conclusion and Enlightenment

From the perspective of systematic thinking, this paper introduces the Three-stage DEA method to study the technical efficiency of higher education in China for the first time, and combines the Super-efficiency DEA analysis to effectively distinguish the provinces and cities that belong to the frontier of higher education production. The results show that: (1) external environmental factors and random errors have an important impact on the efficiency of higher education; (2) The per capita disposable income of residents has a favorable impact on the efficiency of higher education, and the proportion of primary and secondary education funds in

ISSN: 2688-8653

education funds is an unfavorable factor to improve the efficiency of higher education; (3) Most provinces and cities have mature management ability in higher education; (9) There are obvious differences in the Super-efficiency values between provinces and cities with DEA efficiency of higher education in China, and there are 19 provinces and cities at the forefront of higher education technical efficiency; Scale efficiency is the key factor affecting the comprehensive technical efficiency of higher education, and the adjusted scale efficiency of higher education in some provinces and cities is obviously lower than the pure technical efficiency.

Systematic thinking requires that the direction of thinking about higher education should be aimed at the overall situation and the whole, starting from the overall situation, the whole, the structure and the environmental elements, and paying attention to the rationality and function of the internal structure of the system. The above conclusions show that the higher education system in most provinces and cities in China is DEA effective, but there are also some provinces and cities with scale inefficiency or management level to be improved, and there is still room for improvement in the technical efficiency of higher education. This paper gets the following three inspirations: (1) Improve environmental factors to tap the potential of higher education efficiency, such as improving the income level of university teachers, stimulating teachers' enthusiasm for teaching and scientific research and innovation, and improving the allocation efficiency of university educational resources. (2) All provinces and cities should formulate corresponding countermeasures according to their own higher education efficiency, and 15 provinces and cities at the forefront of higher education technical efficiency should actively seek new breakthroughs, continue to deepen institutional reform and seek management innovation; Tibet, Qinghai, Ningxia, Hainan, Shandong, Jilin and Beijing should pay attention to improving the scale efficiency of higher education, optimizing the allocation of educational resources and increasing the scale efficiency; Shaanxi should devote itself to improving the management level, introducing new management concepts, perfecting teachers' incentive mechanism and teaching evaluation system, etc.; Guizhou, Yunnan, Gansu, Jiangxi, Fujian, Liaoning, Chongqing and other provinces and cities should take a two-pronged approach to improve pure technical efficiency and scale efficiency. (3) Strive to promote the construction of world-class universities and first-class disciplines, focus on subsidizing some universities in the central and western regions to improve their school-running level, pay attention to introducing high-quality educational resources in universities, and improve the modern university system with Chinese characteristics.

References

[1] Trow. Problems in the transition from elite to mass higher education [J]. Translated by Wang Xiangli. Foreign Education Materials, 1999 (1): 1-22.

[2] Leon Lai Ming. Discussion on the self-organized development path of higher education in China [J]. Journal of Systems Science, 2011, 19 (3): 87-92.

[3] Wang Chaohui, Feng Caiyun. On the relationship between input and output of higher vocational education [J]. Vocational and Technical Education, 2015, 36 (5): 33-36.

[4] Yi Ming, Peng Jiachao, Yao Zhang. Comprehensive evaluation of input-output efficiency of higher education in China: based on Windows-Malmquist index method [J]. China Management Science, 2019, 27 (12): 32-42.

[5] Han Haibin, Li Quansheng.Research on the evaluation of input-output efficiency of colleges and universities based on AHP/DEA [J]. Fudan Education Forum, 2009, 7 (1): 64-68.

[6] Guan Yonggang. Efficiency analysis of higher education resource allocation based on Super-efficiency DEA model [J]. Heilongjiang Higher Education Research, 2019, 37 (2): 84-88.

ISSN: 2688-8653

[7] JEAN-PASCAL G, NICOLAS P.The geographical effectiveness of education and research: The ranking of U.S. universities [J]. Society-Economic Planning Sciences, 2017, 7 (3): 44-55.

[8] ARISTOVNIK A.ICT expansions and education outputs/outcomes in selected developed countries [J]. Campus-Wid e Information Systems, 2013, 30 (3): 222-230.

[9] Duan Xiaomei. Super-efficiency DEA evaluation of scientific research performance of Chinese universities under systematic thinking [J]. Journal of Systems Science, 2019, 27 (4): 51-54.

[10] SAHNEYS, THAKKARJ. A comparative Assessment of the performance of select higher education Institutes in india [J]. Quality As Surancein Education, 2016, 24 (2): 278-302.

[11] SIMAR L, WILSON P.Estimation and Inferencein two-stage, Semi-parallel models of production processes [J]. Journal of Economics, 2007, 136 (1): 31-64.