DOI: 10.53469/jrve.2024.06(08).01

Research on Allocation Efficiency of Higher Education Resources in China

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Abstract: ***Education has the purpose of serving economic and social development, and the efficiency of resource allocation in the higher education system has become an important factor affecting the quality of economic development. Based on the panel data of China's higher education from 2014 to 2023, the adoption of data envelopment analysis (DEA) model was used to evaluate the efficiency of China's higher education resource allocation. The evaluation results show that China's higher education resource allocation efficiency has not reached the effective state of DEA, but the overall level is high; there are certain differences in the higher education resource allocation efficiency in different regions; the negative growth of China's higher education resource allocation efficiency is obvious, and technological progress is the main factor hindering the improvement of total factor production efficiency. Therefore, based on the relevant policies, this paper puts forward rationalization suggestions for the improvement of the allocation efficiency of higher education resources in China from the perspectives of human, financial and material resources.***

Keywords: Higher Education, DEA-Mulmquist Model, Investments Efficiency**.**

1. Introduction

Firstly, the introduction and execution of the Belt and Road offer novel prospects for the advancement of higher education in China, which initiative aims to foster interconnection and mutually beneficial collaboration among the countries along the route. As the globalization of higher education plays a crucial role in fostering talent development, scientific and technological advancements, and cultural interactions, it is important to study the efficiency of the allocation of resources in higher education. Secondly, high vocational education along the "Belt and Road" is comparatively lacking even though it is a kind of high education. Furthermore, China's development relies on the world, just as the world's development relies on China. Within this framework, the globalization of higher education not only serves to bolster China's influence and international dialogue, but also plays a beneficial role in the global integration process. This study aims to investigate the efficiency of allocating resources in higher education, focusing on three key aspects: human, financial, and material resources. Additionally, the study analyzes strategies to address the geographical imbalance resulting from the current resource allocation practices, with the ultimate goal of enhancing the overall efficiency of resource allocation in higher education.

2. Literature Review

Based on the current research conducted both domestically and internationally, the majority of studies on higher education efficiency utilize the DEA-ANN model, three-stage model, and DEA-Tobit model. However, this study distinguishes itself by employing a novel approach at the methodological level. Specifically, it combines the DEA and Malmquist index models, taking into account both dynamic and static factors. Moreover, this study goes beyond the basic education stage and delves into a more comprehensive analysis of higher education, exploring its deeper levels. The advancement in higher education is demonstrated through the innovative application of the DEA and Mulmquist index model to assess the effectiveness of investments in higher education. The study's methodology breakthrough the filed by combining the DEA and Mulmquist index models, incorporating both dynamic and static elements to assess the efficiency of higher education investment. Furthermore, it surpasses the basic education stage and delves into the deeper realm of higher education.

From the foreigner's prospect, Canada, Vietnam, and Romania are the primary countries at the international level that utilize DEA-related models and are engaged in researching efficiency in higher education. For instance, Jauhar Sunil Kumar, Zolfagharinia Hossein, et al. (2023) examined the present condition of university education in Canada using DEA-ANN modeling [1]. Tran Thien Vu and Pham Thao Phuong (2022) investigated the effectiveness of higher education institutions in Vietnam from 2012 to 2016 [2]. Olariu Gabriela Vica and Brad Stelian (2022) used a combination of traditional CRS-DEA and VRS-DEA models to analyze the Romanian higher education system [3]. In a separate study, Gabriela Vica Olariu, Stelian Brad, et al (2017) examined higher education using officially published university data from 2012 to 2015, supplemented with CRS-DEA and VRS-DEA models [4]. Ramón Fuentes, Begoña Fuster et al. (2016) employed a three-stage framework to evaluate educational efficacy [5].

From the domestic prospect, DEA models are created to analyze the efficiency of universities in all 31 provinces of China using the following approach: Siti Fatimah and Umi Mahmudah (2019) employed a two-stage DEA-VRS model and a super-efficiency model study Primary education [6]. Sangchan Kantabutra (2012) utilized the super-efficiency DEA model to investigate the efficiency of higher education resources directly under the Ministry of Education in China [7]. In 2024, the researchers used the highly efficient DEA model and Malmquist productivity index to thoroughly examine the input-output efficiency of the resources in Chinese universities under the Ministry of Education [8]. Additionally, Fang Yongheng and Lan Chunxiang (2020) employed the three-stage super-efficient SBM model to evaluate the efficiency of universities [9].

From the economic circle prospect, The DEA-related models are employed to analyze the efficiency of higher education in the West, such as Chengdu-Chongqing Economic Circle. For instance, Olariu Gabriela Vica and Brad Stelian (2022) conducted a study efficiency of universities in western China by using the super-efficient DEA Windows-Malmquist-Tobit model [10]. Li RC, Luo YY, Chen B (2023) et al. used the DEA-Malmquist model to examine the efficiency and level of total factor productivity (TFP) in the Chengdu-Chongqing Twin Cities Economic Circle [11]. Additionally, in 2014, Nazarko and Šaparauskas evaluated the research performance of 19 Polish universities of technology [12].

From the country aspect, Temoso Omphile, Tran Carolyn Thi Thanh Dung and Myeki Lindikaya et al. (2023) employed the network-based DEA method to examine the performance of South African higher education institutions in a network structure of teaching and research for the period 2009–2016 [13]. Tran Thien Vu, Pham Thao Phuong and Nguyen Mai Huong et al. (2023) aims to examine the economic efficiency of Vietnamese 172 higher education (HE) institutions within the 2012–2016 inclusive period through the Data Envelopment Analysis (DEA) approach [14]. Olariu Gabriela Vica and Brad Stelian (2022) evaluates the relative efficiency of study programs in Romanian higher education using the DEA method. This study is based on 38 study programs from a public university in Romania, using a traditional DEA approach: CRS-DEA and VRS-DEA models, with an output orientation for three academic years [15].

Different from the prevailing approach currently, The study utilizes the DEA model and the Mulmquist index model, combining with static and dynamic analysis to assess the efficiency of higher education investment. Furthermore, The results offer insights for enhancing education quality in the Belt and Road region.

3. Construction of the Model and Selection of Indicators

3.1 Construction of the Model

3.1.1 CCR Model

The DEA method, known as Data Envelopment Analysis, was introduced by A. Charnes and W. W. Cooperin 1978. The method used to assess the relative effectiveness of input-output combinations in a static setting by establishing a decision-making unit (DMU) with multiple inputs and outputs. Compared to other models, the DEA method offers the advantages of not requiring weighting assumptions or quantitative manipulation of data. Traditional DEA models consist of the BBC model and the CCR model, which respectively represent the variable perspective of returns to scale and the constant perspective of returns to scale.

Using CCR as an illustration, the formula for the CCR model is as follows:

$$DMU = \begin{cases} x_i = (x_{1,i}, x_{2,i}, \cdots, x_{w,i}) \\ y_i = (y_{1,i}, y_{2,i}, \cdots, y_{w,i}) \\ i = 1, 2, \cdots, n \end{cases} \tag{1}$$

Equation (1) The linear solution for the input-output efficiency value of each Decision Making Unit (DMU) is as follows:

$$\min_{\gamma,\lambda} \lambda$$
$$\text{s. t.} \begin{cases} \sum_{i=1}^{n} x_i \gamma_i \leqslant \lambda x_0 \\ \sum_{i=1}^{n} y_i \gamma_i \geqslant \lambda y y_0 \\ \gamma_i \geqslant 0, i = 1, 2, \cdots, k, \cdots n \end{cases} \tag{2}$$

3.1.2 Setting up the Malmquist model

Sten Malmquist initially introduced the Malmquist index, which was subsequently modified by Fare et al. to transform it from a theoretical index to an empirical index. In addition, The Malmquist index is a nonparametric measure.

The production frontier party measures changes in total factor productivity (TFP) and decomposes them.

TFP changes are transformed into technical progress (EC) and technical efficiency changes (TC) assuming constant returns to scale (CRS) in the analysis. Assuming variable returns to scale (VRS), changes in technical efficiency are further broken down into pure technical efficiency change. Pech and scale efficiency refer to the measurement and evaluation of the effectiveness and productivity of a system or process.

The Malmquist productivity change index is advantageous because it addresses the limitations of the single static level of DEA through its dynamic examination. The Malmquist index evaluates efficiency by analyzing the change in efficiency from period t to period t+1, using the technical level of period t as the benchmark for a given condition in period t or using the technical level of period t as the benchmark for a given level in period t+1. The Malmquist index is calculated using two formulas, namely Eq. Three and Eq. 4.

$$\begin{aligned} M_i^1 &= D_i^1(x^1, y^t)/D_i^1(x^{1+1}, y^{1+1}) \\ M_i^{1+1} &= D_i^{1+1}(x^1, y^1)/D_i^{1+1}(x^{1+1}, y^{1+1}) \end{aligned} \tag{3}$$

The total factor productivity, which quantifies the change in efficiency from period t to t+1, is calculated by taking the geometric mean of the indices in equations 3 and 4 as the standard.

$$\begin{aligned} &\mathrm{TFP}(x^1, y^1, x^{1+1}, y^{1+1}) \\ &= \frac{D_i^{t+1}(x^{1+1}, y^{1+1})}{D_i^1(x^1, y^1)} \left[\frac{D_i^1(x^1, y^1)}{D_i^{1+1}(x^1, y^1)} \times \frac{D_i^1(x^{1+1}, y^{1+1})}{D_i^{1+1}(x^{1+1}, y^{1+1})} \right]^{\frac{1}{2}} \end{aligned} \tag{4}$$

3.2 Indicators Selection

Checking the effectiveness of allocating resources in higher education can enhance the organization of resource allocation. Human, financial, and material resources, which are the fundamental components of resource allocation, play a crucial role in assessing resource allocation efficiency.

Table 1: Input and Output Indicators for the Allocation of Preschool Education Resources under DEA Analysis

Destination layer	Criteria layer	variable
The input variables	Financial input	Higher education funding
	Material input	Count of Higher Education Institution
	Human input	Number of full-time teachers
The output variables	quality of education	Three domestic patent applications
	quantity of education	Number of personnel with associate senior professional titles

4. Empirical Analysis

4.1 Static Analysis of CCR Model

This study utilizes the DEA model to examine the technical efficiency of resource allocation in higher education within the Belt and Road. The technical efficiency value is determined by multiplying the pure technical efficiency and scale efficiency.

Table 2: Evaluation Results of Provincial Higher Education Resource Allocation Efficiency under the Belt and Road Initiative from 2014 to 2023

Province/Municipality	2014			2015			2016			2017			2018		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Inner Mongolia	0.358	0.346	0.875	0.359	0.347	0.346	0.346	0.345	0.296	0.394	0.337	0.326	0.394	0.337	0.326
Liaoning	0.904	0.862	1	0.924	0.882	0.876	0.889	0.877	0.746	0.916	0.773	0.744	0.916	0.773	0.744
Jilin	0.724	0.706	0.95	0.721	0.704	0.696	0.702	0.694	0.606	0.779	0.679	0.667	0.779	0.679	0.667
Heilongjiang	0.757	0.731	1	0.791	0.764	0.763	0.76	0.758	0.648	0.828	0.706	0.681	0.828	0.706	0.681
Shanghai	1	0.994	1	1.227	1	0.98	1.249	1	0.924	1.117	1	1.004	1.117	1	1.004
Zhejiang	1	0.924	1	1.194	1	0.91	1.294	1	0.863	1.03	0.877	0.847	1.03	0.877	0.847
Fujian	0.646	0.627	0.935	0.664	0.644	0.64	0.653	0.649	0.56	0.743	0.639	0.621	0.743	0.639	0.621
Guangdong	1	0.965	1	1.234	1	0.999	1.444	1	0.851	1.299	1	0.961	1.299	1	0.961
Guangxi	0.474	0.459	0.895	0.497	0.48	0.479	0.473	0.472	0.404	0.535	0.458	0.443	0.535	0.458	0.443
Hainan	0.187	0.185	1	0.202	0.201	0.193	0.183	0.176	0.163	0.221	0.204	0.191	0.221	0.204	0.191
Chongqing	0.694	0.682	0.939	0.736	0.723	0.712	0.717	0.706	0.624	0.803	0.709	0.704	0.803	0.709	0.704
Yunnan	0.407	0.388	0.866	0.413	0.394	0.388	0.388	0.382	0.319	0.437	0.361	0.347	0.437	0.361	0.347
Shanxi	0.832	0.805	0.94	0.855	0.827	0.824	0.836	0.833	0.714	0.952	0.816	0.789	0.952	0.816	0.789
Gansu	0.35	0.339	0.848	0.381	0.37	0.368	0.372	0.37	0.318	0.462	0.397	0.385	0.462	0.397	0.385
Qinghai	0.097	0.095	1	0.095	0.093	0.092	0.092	0.091	0.08	0.105	0.093	0.091	0.105	0.093	0.091
Ningxia	0.147	0.146	0.987	0.168	0.166	0.163	0.168	0.164	0.147	0.175	0.157	0.157	0.175	0.157	0.157
Xinjiang	0.263	0.254	0.89	0.27	0.262	0.261	0.258	0.257	0.22	0.285	0.245	0.237	0.285	0.245	0.237
Province/ Municipality	2019			2020			2021			2022			2023		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Inner Mongolia	0.333	0.316	0.315	0.333	0.316	0.315	0.333	0.316	0.315	0.311	0.301	0.3	0.76	0.297	0.83
Liaoning	0.72	0.684	0.681	0.72	0.684	0.681	0.72	0.684	0.681	0.639	0.619	0.615	0.65	0.628	0.801
Jilin	0.618	0.589	0.579	0.618	0.589	0.579	0.618	0.589	0.579	0.534	0.502	0.495	0.589	0.502	0.774
Heilongjiang	0.685	0.651	0.647	0.685	0.651	0.647	0.685	0.651	0.647	0.601	0.58	0.576	0.629	0.563	0.822
Shanghai	1.221	1	0.971	1.221	1	0.971	1.221	1	0.971	1.143	1	1	0.151	1	1
Zhejiang	0.864	0.798	0.793	0.864	0.798	0.793	0.864	0.798	0.793	0.843	0.818	0.812	0..045	0.815	1
Fujian	0.673	0.64	0.634	0.673	0.64	0.634	0.673	0.64	0.634	0.677	0.65	0.644	0.988	0.657	0.886
Guangdong	1.201	1	1.072	1.201	1	1.072	1.201	1	1.072	1.021	1	0.996	0.033	1	1
Guangxi	0.475	0.452	0.448	0.475	0.452	0.448	0.475	0.452	0.448	0.492	0.475	0.471	0.449	0.48	0.765
Hainan	0.214	0.209	0.193	0.214	0.209	0.193	0.214	0.209	0.193	0.223	0.2	0.195	0.504	0.246	0.835
Chongqing	0.723	0.69	0.674	0.723	0.69	0.674	0.723	0.69	0.674	0.746	0.692	0.68	0.924	0.678	0.824
Yunnan	0.348	0.331	0.329	0.348	0.331	0.329	0.348	0.331	0.329	0.342	0.333	0.332	0.442	0.333	0.712
Shanxi	0.834	0.793	0.788	0.834	0.793	0.788	0.834	0.793	0.788	0.832	0.805	0.799	0.613	0.808	0.888
Gansu	0.385	0.366	0.363	0.385	0.366	0.363	0.385	0.366	0.363	0.382	0.367	0.363	0.593	0.365	0.778
Qinghai	0.081	0.077	0.076	0.081	0.077	0.076	0.081	0.077	0.076	0.079	0.074	0.073	0.37	0.112	0.824
Ningxia	0.153	0.146	0.142	0.153	0.146	0.142	0.153	0.146	0.142	0.149	0.136	0.133	0.96	0.142	0.821
Xinjiang	0.205	0.195	0.193	0.205	0.195	0.193	0.205	0.195	0.193	0.167	0.164	0.163	0.154	0.166	0.719

According to the analysis in Table 2, the overall technical efficiency is greater than 0.9 but less than 1, which indicates that it is still in an inefficient state. When looking at specific provinces and cities, the technical efficiency values of 7 provinces and cities, including Shanghai, Fujian, Guangdong, Guangxi, Hainan, Shaanxi, and Gansu, are all greater than 1.

The overall technical efficiency of the land and sea Silk Road is lower than the scale efficiency value. The overall provincial and municipal scale efficiency is greater than or divided by the pure technical efficiency, except Inner Mongolia and Chongqing, two provinces and municipalities, whose scale efficiency is lower than the pure technical efficiency. From the geographical location, Inner Mongolia and Chongqing are part of the land Silk Road.

The lack of high-quality talent in Inner Mongolia, caused by inadequate infrastructure, has hindered the progress of higher education in the region. For Chongqing, The absence of a budget for funding higher education has a negative impact on the effectiveness of investing in higher education. In addition, the insufficient allocation of funding for higher education has a detrimental impact on the quality of teaching, research, and faculty development. The current focus on enhancing the efficiency of higher education resource allocation, as well as minimizing investment costs and maximizing investment benefits.

4.2 Dynamic Analysis of Malmquist Inde

According to the analysis in Table 3, in terms of considering the static perspective, the average value of total factor productivity in higher education has remained consistently close to 1 from 2014 to 2023. From a dynamic standpoint, the total factor growth rate exhibits a consistent and regular pattern with minor fluctuations. This table demonstrates that investing in higher education yields high efficiency and contributes to the advancement of higher education at this stage. Nevertheless, when considering future trends, it is important to acknowledge that total factor productivity remains susceptible to the ongoing possibility of a persistent decrease.

Table 3: Temporal Variation of Total Factor Productivity in Provincial Higher Education Resource Allocation Efficiency under the Belt and Road Initiative from 2014 to 2023

Year	Technical efficiency change	Production efficiency change	Pure technical efficiency change	Sale efficiency change	Total factor productivity
2014-2015	1	1.035	1.003	0.998	1.035
2015-2016	1.002	1.003	1.002	1	1.004
2016-2017	0.991	1.057	0.992	0.999	1.048
2017-2018	0.984	1.031	0.998	0.985	1.014
2018-2019	1.004	1.07	1	1.004	1.074
2019-2020	0.982	0.961	0.99	0.991	0.943
2020-2021	0.981	0.992	0.993	0.998	0.973
2021-2022	1.006	1.006	1.002	1.004	1.102
2022-2023	0.89	1.447	1.065	0.836	1.289

From a decomposition perspective, the static analysis up until 2021 serves as the turning point in time. During the early period, the total factor productivity is nearly 1, indicating a reasonable investment layout in higher education. The technical efficiency, pure technical efficiency, and scale efficiency all play coordinated roles in this structure. From a dynamic perspective, between 2021 and 2022, there is a positive correlation between the change in total factor productivity, production efficiency, and pure technical efficiency. The rate of increase in these factors also accelerates, suggesting that production efficiency and the contribution of technological progress to total factor productivity gradually increase during this period. The decrease in scale efficiency is a result of the rise in student enrollment in higher education and the growth of higher education institutions, both of which contribute to the increased cost of managing higher education. Insufficient education funding relative to the rising cost of management exposes the disadvantages of investing in higher education, specifically in terms of investment inefficiency.

From 2014 until now, the decomposition values indicate that the most significant decline is observed in terms of the change in productive efficiency, followed by the change in technical efficiency, and finally, the change in pure technical efficiency.

5. Conclusion and Recommendation

5.1 Conclusions

By combining the analysis of the current state of higher education development with a strong education country's development strategy, it is important to formulate both long-term and short-term education investment plans and optimize the allocation of resources in higher education to enhance staffing efficiency:

(1) Enhancing the allocation of higher education resources based on manpower needs and value excellence. From the perspective of human resources, higher education plays a crucial role in developing highly skilled individuals and has the responsibility of finding a talent cultivation model that aligns with the needs of the country and society.

(2) Utilizing physical force to facilitate the implementation of resource allocation in higher education. The construction of infrastructure is an integral part of higher education development.

(3) Funding to spearhead the effective distribution of resources in higher education from a financial standpoint. implementing an effective financial funding management mechanism is beneficial for maintaining a balance between national income and expenditure to establish a scientific education.

5.2 Suggestions

According to the results, The efficiency of higher education resource allocation along the Belt and Road needs to be improved, and there are significant differences between the Maritime Silk Road and the Silk Road. So the study presents pertinent recommendations regarding human, material, and financial resources. Simultaneously, considering the difference between the Maritime Silk Road and the Land Silk Road, the government can adapt its policies accordingly. What's more, favoring the land-based Belt and Road and providing preferential treatment and will enhance the overall allocation of national higher education resources and optimize their resource allocation efficiency. Furthermore, combining the analysis of the current state of higher education development with a strong education country's development strategy is very necessary. In addition, it is important to formulate both long-term and short-term education investment plans and optimize the allocation of resources in higher education to enhance staffing efficiency. Based on the study, the analysis can do a little contribution to optimize higher education resources and serve as a reference. In the future, the construction of higher education will further take into account the overall planning of resource allocation issues such as human resources, finances, and materials, aiming to Improve the comprehensive level of higher education.

Acknowledgments

This research was supported by the Major Project of Key Research Base of Humanities and Social Sciences of Ministry of Education, "Research on Modernization of Rural Education in Ethnic Areas in Chinese Style" (Project No. 22JJD880015); General project of the Sichuan Provincial Research Base for forging a strong sense of the Chinese national community "Research on the integration of forging a strong sense of the Chinese national community into the teaching of ideology and politics courses in colleges and universities" (Project No. SC2024Z028). Project of the Key Research Base for Humanities and Social Sciences of the Sichuan Federation of Social Sciences and the Department of Education, "The Logical Reasoning and Practical Path of Emei Wushu in Casting a Firm Consciousness of the Chinese National Community" (Project No. TY2024224).

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