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Measurement and Spatio-Temporal Evolution Analysis of China's Higher Education Resource Allocation Efficiency

Hongzhan Li[1,2,a,*], Jianghua Luo[1,b], Ju Shen[1,3,c], Aiyu Xie[4,d]

[1]Faculty of Education, Southwest University, Chongqing, 400715, China
[2]School of Marxism, Chongqing University of Technology, Chongqing, 400054, China
[3]Chongqing City Management College, Chongqing, 401331, China
[4]School of Management, Chongqing University of Technology, Chongqing, 400054, China
[a]lihongzhan@cqut.edu.cn, [b]swusun@swu.edu.cn, [c]shenju21@163.com, [d]Xieaiyu39@stu.cqut.edu.cn
**Corresponding author*

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Abstract: The allocation of higher education resources is an important component in the improvement of regional education quality, and one of the most important issues in addressing the imbalance and lack of educational resources is how to achieve the higher education resources allocation efficiency (HERAE) in various geographical areas. This study quantitatively evaluated China's HERAE by constructing an input-output indicator system and applying the DEA model, and further analyzed its spatio-temporal evolution characteristics. The study found that China's HERAE shows a high level in general, but there exist significant differences between regions, indicating the characteristics of "leading in the east area, second in the center area, and lagging in the west aera". This study aims to offer a theoretical foundation for enhancing the effectiveness of resource allocation in China's higher education system and encouraging the advancement of higher education.

1. Introduction

As the core of the national innovation system and the driving force of social development, the efficiency of higher education's resource allocation is directly related to regional education equity and quality improvement[1-3]. As information technology has advanced along the course of educational reforms, the unequal distribution of educational resources between nations and regions has emerged as a major global concern[4,5]. To some extent, China as the largest developing country in the world has the largest higher education system around the world and the rapid economic development has led to the continuous expansion of higher education in China, but the problem such as the imbalance and insufficiency in the distribution of educational resources has also become more and more prominent at the same time[6,7]. According to the Chinese government's Outline of the Plan for the Construction of a Strong State of Education from 2024 to 2035, the design of higher education is a crucial component of the institution's development strategy and contributes significantly to the establishment of a strong state of education. In addition, although the Chinese government's financial investment in education has been expanding in recent years (the total amount invested in national

education was 6132 billion yuan accounting 4.01% of China's GDP in 2022), there is still much room for improvement in the HERAE such as the fine distribution of education revenues, faculty and research platforms, and so on[8,15,16]. Therefore, it is of great significance to accurately assess the efficiency of higher education resource allocation and further reveal its spatial and temporal evolution trends in different provinces, in order to rationally allocate higher education resources, realize educational equity and promote the high-quality development of higher education[8,12,17].

2. Materials and methods

2.1 Study area and data

Considering the completeness of the data, we selected 29 provinces in China as the research areas and this study gathered statistical data mainly from the China Statistical Yearbook, the China Science and Technology Statistical Yearbook, and the China Education Statistical Yearbook, primarily for the 2011–2022 period.

2.2 Indicator selection

Higher education resource allocation is a composite system with multiple inputs and outputs. Based on previous studies, this study constructed an evaluation system for the efficiency of China's higher education resource allocation from the perspectives of inputs and outputs and the specific indicator system is shown in Table 1.

Table 1 The evaluation index system of HEREA in China

Indicator type	Level I	Level II	Units	Weights	Indicator source
Input	Labor inputs	Full-time teachers in higher education	Per person	0.367	[9]
	Finance inputs	Investment in education	billions		[1]
	Material input	Investment in fixed assets	billions		
Output	Social benefit outputs	GDP	billions	0.244	[10]
		Number of higher education institutions	/		[11]
	Educational research outputs	Number of patents granted for inventions	/	0.389	[12]
		Technology market turnover	10,000 yuan		[10]
		Number of graduates from tertiary institutions	/		[10]

2.3 Methodology

2.3.1 Entropy weighting method

In order to identify the weights of the HERAE system's first-level indicators, this study presents the entropy weighting method. As an objective assignment method, the entropy method is based on the actual observed values of each evaluation indicator as the original data, and through the calculation of information entropy as a means of assessing the distribution dispersion of the data. The calculation are as follows:

$$\begin{cases} X_{ij}^{'} = \dfrac{X_{ij} - \min\left\{X_{1j},\cdots,X_{nj}\right\}}{\max\left\{X_{1j},\cdots,X_{nj}\right\} - \min\left\{X_{1j},\cdots,X_{nj}\right\}} \text{(positive variables)} \\ X_{ij}^{'} = \dfrac{\max\left\{X_{1j},\cdots,X_{nj}\right\} - X_{ij}}{\max\left\{X_{1j},\cdots,X_{nj}\right\} - \min\left\{X_{1j},\cdots,X_{nj}\right\}} \text{(negative variables)} \end{cases} \tag{1}$$

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \tag{2}$$

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \times \ln(P_{ij}) \tag{3}$$

$$d_j = 1 - e_j \tag{4}$$

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{5}$$

Where X_{ij} is the raw value of the jth indicator of the evaluation object i and n is the sample size of the evaluation indicator; P_{ij} is the normalization matrix; e_j is the information entropy; d_j is the differentiation factor; W_j is the weight.

2.3.2 Data envelopment analysis

Data Envelopment Analysis (DEA) is a linear programming model proposed in the field of operations research. Unlike previous research models, the DEA model evaluates a system's degree of development from an efficiency standpoint and can show how variables are causally related[13,14]. The SBM-DEA model has a good applicability to the measurement of ecological, energy, and sustainability efficiency.

$$\rho^{*} = \min\rho = \min \frac{1 - (\frac{1}{\mathrm{V}} \sum_{\mathrm{v}=1}^{V} \frac{\mathrm{s}_{\mathrm{v}}^{\mathrm{x}}}{\mathrm{x}_{\mathrm{v}}^{\mathrm{k}'}}}{1 + \left[\frac{1}{1+\mathrm{U}} \left(\sum_{u=1}^{U} \frac{s_u^y}{y_u^k} + \sum_{i=1}^{I} \frac{s_j^b}{b_i^{k'}} \right)\right]} \tag{6}$$

$$\sum_{k=1}^{K} z_k^y y_u^k - s_u^y = y_u^{k'}, u = 1\cdots, \quad U; \quad s_u^y \geq 0 \tag{7}$$

$$\sum_{k=1}^{K} z_k^y x_v^k - s_v^x = x_v^{k'}, v = 1\cdots, \quad V; \quad s_v^x \geq 0 \tag{8}$$

$$\sum_{k=1}^{K} z_k^y b_i^k - s_i^b = b_i^{k'}, i = 1,2\cdots N, \quad s_i^b \geq 0 \tag{9}$$

Where V, U, N denote input indicators, desired outputs, and undesired outputs, respectively. $(S_u^y, S_i^b, S_v^x), (y_u^k, b_i^k, x_v^k)$ and z_k^y are input slack variables and output slack variables. ρ^* denotes the final efficiency measure, and the larger $\rho^*$is means the higher the level of HERAE in the region.

3. Results

3.1 The measuring of HERAE

In terms of the overall fluctuation, the years with high average values of HERAE are mainly centered on 2011 (0.87) and 2019 (0.85). In addition, the overall trend of change for the HERAE level in 29 provinces is erratic, first declining, then rising, and ultimately smoothing out at the end. Specifically, the first stage of change is 2011-2017, from the average score of 0.87 in 2011 declined to 2007 scored 0.78. The second stage of change is 2018-2020 of some increase. The third stage is 2021-2022, the degree of change of HERAE in 29 provinces in China in these years is small, and the overall are maintained at the average level of 0.80 situation. The overall 12-year HERAE score for China's 29 provinces is centered in the score ranges of 0-0.5 and 1-1.2 which are already at a high level (Fig.1).

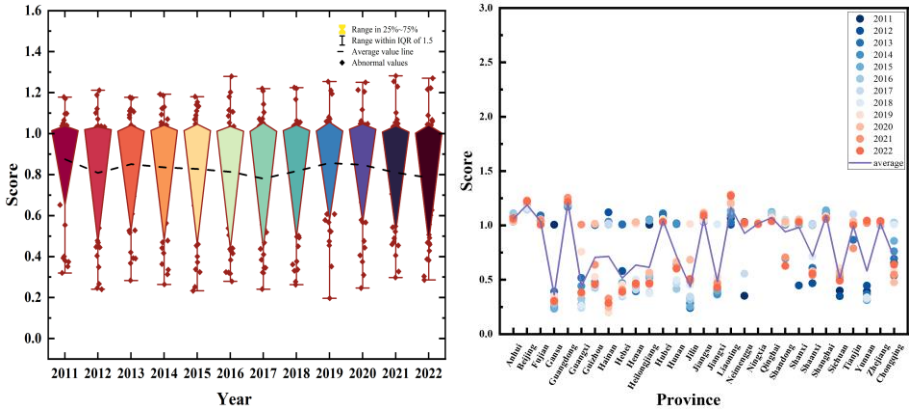


Figure.1 The overall change trend of the HERAE levels in China

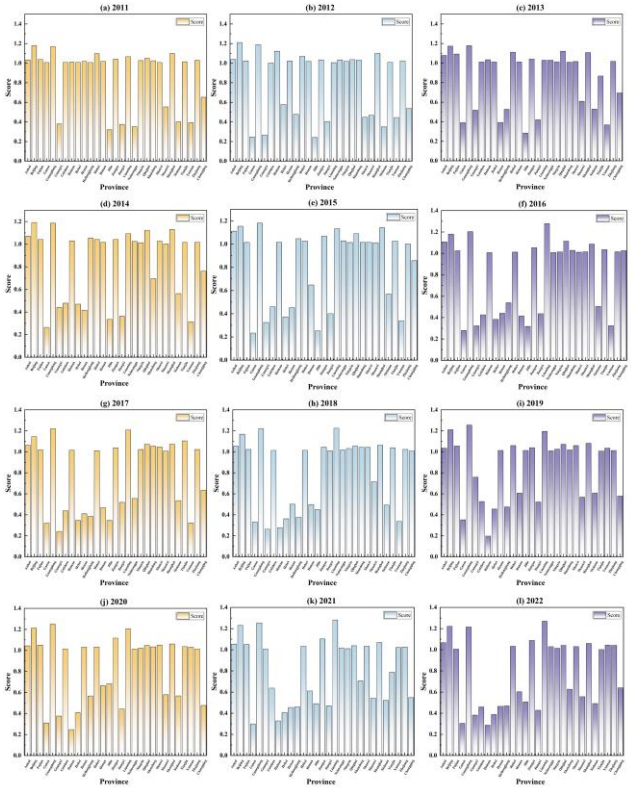
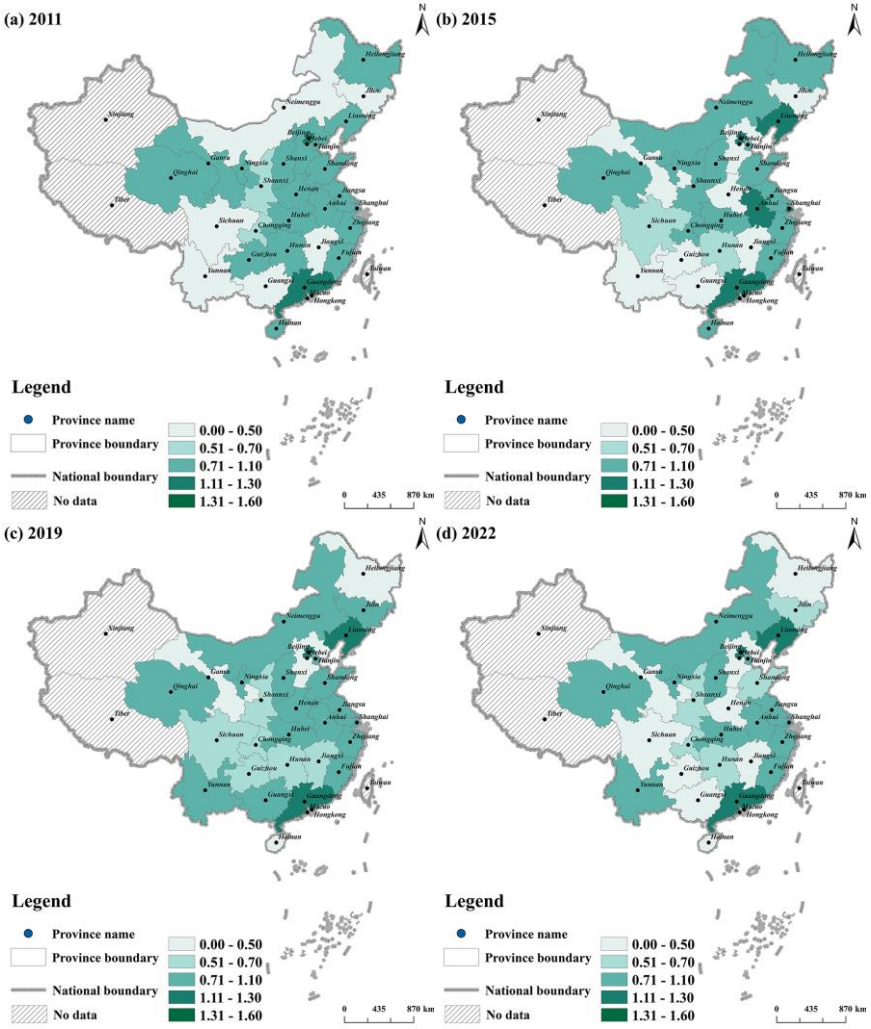


Figure 2 The statistical trend of the HERAE levels in China at different years

Moreover, it can be seen from Fig. 2 and Fig.3 by calculating the average value of the scores from 2011-2022, those with higher HERAE scores are Guangdong Province (1.62), Beijing Municipality (1.19), Liaoning Province (1.17), and Shanghai Municipality (1.09). The lower scores are mainly concentrated in Gansu, Jilin and Guangxi provinces. Due to the great disparities in Chinese resource endowment and economic base, there are significant differences in the investment and allocation of higher education, resulting in large differences in the HERAE among individual provinces. In terms of growth rates, most of the provinces maintained positive changes in HERAE during the study period such as Inner Mongolia's HERAE increasing from 0.35 to 1.02with a growth rate of 65.81%, which is the highest growth rate among all provinces. The HERAE of Yunnan and Liaoning provinces also showed large increases in the study years. These areas are all part of China's border region indicating that the Chinese government has made good progress in its policy of supporting educational resources in disadvantaged areas in recent years. To some extent, this has also contributed to the gradual shift of China's higher education resources towards a more efficient and balanced situation in the future.



Note: The map is based on the standard map No. GS (2020) 4619, which was taken from the Ministry of Natural Resources of China's Standard Map Service website and the base map has not been altered.

Figure 3 The HERAE's spatial- temporal distribution in China.

4. Discussion

This study utilized the DEA to measure the temporal and spatial evolution of the HERAE in 29

provinces in China from 2011 to 2022, in an attempt to reveal the dynamic characteristics of China's HERAE and its regional differences. From 2011 to 2022, the HERAE in China generally shows a fluctuating change of decreasing, then increasing, and gradually stabilizing at last, a trend that undoubtedly reflects the challenges faced by China's higher education resource allocation at different stages and the continuous efforts in the term of adjusting the imbalance of education resources by government policies. In terms of regional differences, there are significant differences in HERAE in different provinces and large fluctuations during the study period which is undoubtedly closely related to the regional imbalance of China's resource endowment and economic base. Regions with higher levels of economic development tend to be able to invest more resources in higher education development and have more advantages in resource utilization efficiency. Eastern coastal regions such as Guangdong, Beijing, and other provinces have higher HERAE scores, while central and western regions like Gansu, Jilin, Guangxi and other places have higher scores, and this discrepancy illustrates the significant influence of the degree of regional economic growth on the effectiveness of allocating resources for higher education.

However, HERAE in most provinces showed positive growth during the study period. In recent years, the Chinese government's policy of supporting educational resources in disadvantaged areas has achieved significant results. Those measures promote the improvement of the efficiency of the allocation of higher education resources such as Inner Mongolia, which establishes the framework for the equitable development of resources for higher education while also assisting in reducing the educational disparity between areas. Although regional disparities still exist, with the continued promotion of policies and optimization of resource inputs, China's higher education resource allocation efficiency is expected to further improve in the future, gradually achieving a more efficient and balanced development trend. Future research can further explore the specific impact mechanisms of different policy tools on HERAE, and how policy innovation and resource allocation optimization can further narrow the efficiency gap and promote the high-quality development of Chinese higher education.

5. Conclusions

The overall level of HERAE in China's 29 provinces shows a fluctuating and decreasing trend. Most of the regions have scores between 0-0.5 and 1-1.2, showing a higher level overall, and the decline in 2021-2022 is mainly due to the transient impact of public health emergencies such as the new crown epidemic; in terms of the geographic dimension, the HERAE level in the eastern region shows a higher level than that in the central-western region, but the Western region has shown more obvious HERAE improvement in recent years, and the overall HERAE tends to be balanced.

Data availability

The authors do not have permission to share data

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Chen, B., Y. Chen, Y. J. Sun, Y. Tong and L. Liu (2024). The measurement, level, and influence of resource allocation efficiency in universities: empirical evidence from 13 "double first class" universities in China. Humanities and social sciences communication 11(1).http://dx.doi.org/10.1057/s41599-024-03461-z

[2] Chu, J. (2020). Innovation and Structural Optimization of Internal Governance Paths in Universities Based on Principal-Agent Theory. Henan Social Sciences 28(06): 118-124

[3] Gan, L., Q. Wen, B. Lev and W. Jiang (2023). Tourism ecological security evaluation based on dynamic super-efficiency network SBM from the perspective of all-for-one tourism. Journal of Cleaner Production 429: 139333. http://dx.doi.org/10.1016/j.jclepro.2023.139333

[4] Gebru, M. G., S. Raza and M. S. Khan (2021). Efficiency of Higher Education in the Presence of Shared Inputs using Data Envelopment Analysis. Sains Malaysian 50(11): 3421-3438.http://dx.doi.org/10.17576/jsm-2021-5011-25

[5] Gu, Y. and M. He; (2022). Efficiency Measurement and Strategy Selection of Regional Higher Education Resource "Clustering" Configuration for Economic Growth. Journal of Hebei Normal University (Education Science Edition) 24(06): 107-114.http://dx.doi.org/10.13763/j.cnki.jhebnu.ese.2022.06.013

[6] Han, H. and H. Zhao (2023). Regional Differences and Dynamic Evolution of Higher Education Resource Alocation Efficiency under High - quality Development. Heilongjiang Higher Education Research 41(11): 55-62.http://dx.doi.org/10.19903/j. cnki.cn23-1074/g.2023.11.021

[7] Jiang, Y., S. Liu and Y. Hong (2020). Research on the Higher Education Resource Allocation Efficiency from the Perspective of High-quality Economic Development. Research on Education Development 40(11): 76-84.http://dx.doi.org/10.14121/j.cnki.1008-3855.2020.11.011

[8] Liu, H. and h. Ma (2023). Regional Difference, Dynamic Evolution and Development Forecast of Higher Education Resource Allocation in China. Modern education review(05): 88-99

[9] Pan, X., Y. Xu and Y. Zhao (2020). Regional differences, spatial effects and influencing factors of higher education development in China. Educational Scholarship Monthly (11): 9-18.http://dx.doi.org/10.16477/j.cnki.issn1674-2311.2020.11.002

[10] Wu, J. and Y. Kan (2018). The Empirical Study on the Influence of Education Resource Allocation on Regional Innovation Abilitity. Journal of Jiangxi Normal University (Natural Science Edition) 42(03): 283-290.http://dx.doi.org/10.16357/j.cnki.issn1000-5862.2018.03.11

[11] Wu, J., S. Wang, R. Zhang, M. Zhao, X. Sun, X. Qie, Y. Wang, amp and Finance (2024). Measurement of green innovation efficiency in Chinese listed energy-intensive enterprises based on the three stage Super-SBM model. International Review of Economics. http:http://dx.doi.org/10.1016/j.iref.2024.103819

[12] Xu, H. and M. Li (2019). Analysis of China's higher education resource allocation efficiency: based on BCC and Malmguist model Journal of Nanchang Engineering College 38(02): 88-96

[13] Yang, J. and Y. Zhao (2017). System Dynamic Modeling and Simulation of High-quality Educational Resources Sharing Model. Eurasian Journal of Mathematical Science and Technology Education 13(12): 7985-7993.http://dx. doi.org/10.12973/ejmste/80738

[14] Yao, Y. (2019). Does higher education expansion enhance productivity? Journal of Macroeconomics 59: 169-194. http://dx.doi.org/10.1016/j.jmacro.2018.11.009

[15] Zhang, J., G. J. Feng, S. X. Ying, Z. J. Chen and Y. D. Sun (2024). Efficiency of Educational Resources Investment: Does Financial Expenditure Matter? Emerging Markets Finance and Trade. http://dx.doi.org/10.1080/1540496X.2024.2420607

[16] Zhang, L., Y. Zhao and L. Ya (2025). A Study of the Spatial and Temporal Evolution of China's Higher Education Input Efficiency. Economic and Management Review 41(01): 42-54.http://dx.doi.org/10.13962/j.cnki.37-1486/f.2025.01.004

[17] Zhao, Z. and X. Yu (2023). The Influence of Economic Development Level and Population Growth on the Allocation of Educational Resources. The Empirical Study of Western China Explorations in Education Science 41(04): 65-73