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Research on the Efficiency of Higher Education Resource Allocation in China's Five Major Economic Circles

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Abstract: ***China's Five Major Economic Circles serve as engines of national economic growth. Studying the efficiency of higher education resource allocation in these regions holds significant importance for promoting China's high-quality economic development. This study employs Data Envelopment Analysis (DEA) to analyze the efficiency of higher education resource allocation and its regional disparities within China's Five Major Economic Circles from 2018 to 2022.The results indicate that the overall efficiency of higher education resource allocation in the Five Major Economic Circles remains relatively low, with pronounced regional disparities. While technological progress across the circles generally maintained a high level and scale efficiency achieved dynamic balance, the decline in pure technical efficiency emerged as the primary cause of the low resource allocation efficiency. Based on these findings, this study proposes several recommendations: establishing a rational and scientific investment system for higher education resources; fully leveraging the spatial spillover effects of higher education; implementing macro-level management system reforms and innovations within universities; and enhancing the external coordination and integration of advanced scientific and technological resources. These measures aim to improve the efficiency of higher education resource allocation in the Five Major Economic Circles and further propel China's economic development.***

Keywords: Five Major Economic Circles, Higher Education, Resource Allocation Efficiency, DEA Model.

1. Introduction

Since the 21st century, competition among nations worldwide has intensified significantly across economic, educational, technological, and other domains. The foundation of a nation's competitiveness lies in education and the economy. Consequently, scholars have dubbed the 21st century the new "double-E" era (encompassing Education and Economy) [1]. Globally, governments universally acknowledge the role of higher education in fostering economic development and have implemented diverse educational policies to stimulate economic growth. For instance, Nordic countries have adopted higher education policies emphasizing high welfare and educational equity, while neoliberal states have introduced market-oriented higher education policies.

Within this context, the Chinese government, aligning with global trends, has long accorded high priority to the development of both education and the economy. Higher education, as the primary social activity for cultivating advanced specialized talents and top-notch innovative personnel, provides robust support for high-quality economic development through knowledge, technology, global value chain upgrading, and human capital. It serves as the underpinning mechanism and cornerstone for consolidating high-quality development [2]. China's Five Major Economic Circles—Yangtze River Delta, Guangdong-Hong Kong-Macao Greater Bay Area, Beijing-Tianjin-Hebei Region, Yangtze River Midstream, and Chengdu-Chongqing — collectively account for over 50% of the national GDP. These regions represent the most dynamic engines of China's economic development and provide a strong financial foundation for higher education investment.

The concept of higher education resource allocation originates from a core proposition in economic research: determining "what to produce, how to produce, and for whom to produce" within a given scope. Here, it specifically refers to the organization of relatively scarce human, material, and financial resources within the higher education sector across different uses, according to societal needs. A consensus has emerged within academia that higher education resources are scarce and must be allocated efficiently [3] [4]. In recent years, higher education within the Five Major Economic Circles has achieved progress in areas such as diversified institutional development and spatial adjustment, cultivating top-notch innovative talents, and industry-academia-research collaboration. Nevertheless, challenges persist, including the need to enhance both scale and quality, the lagging growth and proportion of higher education expenditure relative to the regions' population share and economic growth, and insufficient R&D investment and output [5] [6]. Therefore, constructing an input-output evaluation index system for the efficiency of higher education resource allocation within the Five Major Economic Circles, and scientifically and objectively analyzing and assessing the current state of their resource allocation, holds significant theoretical and practical importance for the balanced development of higher education in China.

Data Envelopment Analysis (DEA), proposed by American operations research scientists in 1978 [7], is a non-parametric estimation method frequently used to study the efficiency of input-output relationships in the economic sphere under static conditions within the same period. Its application expanded to educational assessment in the 1990s, and subsequent scholars have validated its appropriateness for evaluating the operational efficiency of higher education institutions [8]. Consequently, this study employs the DEA model to analyze higher education resource allocation issues within the Five Major Economic Circles. It aims to explore strategies for further optimizing the efficiency of higher education resource allocation, effectively advancing the connotative development (quality-focused development) of higher education in these regions, and thereby better serving China's pursuit of high-quality economic development.

2. Research Design

2.1 Research Methodology

The Data Envelopment Analysis (DEA) model is a non-parametric analytical method used to measure the relative efficiency of Decision Making Units (DMUs) with homogeneous outputs and multiple inputs from a static perspective. It holds significant value in efficiency evaluation as it can, to a certain extent, avoid invalidity caused by errors in the assessment process [9].

Traditional DEA encompasses two models: CCR and BCC [10]. Under the assumption of constant returns to scale (CRS), the DEA-CCR model calculates the overall Comprehensive Technical Efficiency (Crste). Under the assumption of variable returns to scale (VRS), the DEA-BCC model calculates Scale Efficiency (Scale) and Pure Technical Efficiency (Vrste) for resource allocation.

Considering the realities of higher education resource allocation, this study assumes variable returns to scale for higher education within the Five Major Economic Circles. It focuses on maximizing output under constrained input conditions. Consequently, the DEA-BCC model is employed. Its formulation is as follows:

$$\begin{cases} \min\theta \\ s.t. \sum_{i=1}^{k} x^i\lambda_i \le \theta x_0 \\ \sum_{i=1}^{k} y_i\lambda_i \ge y_0 \\ \sum_{i=1}^{k} \lambda_i = 1 \\ \lambda i \ge 0, i = 1,2,\cdots,k \end{cases} \quad (1)$$

In **Equation 1**, x^i and y_i represent the input and output variables, respectively, for the i-th DMU. k is the total number of DMUs. λ_i represents the combination proportion of the k decision units used to reconstruct an efficient DMU relative to DMU_i. θ is the comprehensive efficiency score of the DMU, ranging between (0, 1]. When $0 < \theta < 1$, the DMU is DEA inefficient; when $\theta = 1$, the DMU is DEA efficient.

2.2 Indicator Selection

Based on the general theoretical framework for efficiency measurement and drawing on previous research [11], this study categorizes input indicators into three dimensions: human resources, material resources, and financial resources.

Human Resources: Drawing on studies by Zhao Qingnian et al. [12] and Chen Zini et al. [13], the Total Number of Full-time Faculty (persons) is selected.

Material Resources: Referencing studies by Ren Yi et al. [14], Li Hang et al. [15], Zhang Qiang et al. [16], and Kuang Xiaoping et al. [17], the Number of Higher Education Institutions (institutions) and Library Collection Size (thousand volumes) are selected. Financial Resources: Based on research by Ren Yi et al. [18], Shan Le et al. [19], and Tao Fu et al. [20], the Annual Education Expenditure (ten thousand yuan) and Scientific Expenditure (R&D Expenditure) (ten thousand yuan) are selected.

The selection of output indicators follows the principle of representing higher education's three primary functions: talent cultivation, scientific research, and social service. Talent Cultivation: Drawing on Zhou Xiaogang et al. [21] and Jiang Yucheng et al. [22], the Number of Undergraduate and Junior College Students Enrolled (persons) is selected.

Scientific Research & Social Service: This study posits that the scientific research function of higher education generates social benefits, manifested through technology development, innovation, and application, which promote regional industrial restructuring, upgrading, and socio-economic development, thereby serving society and the public. This overlaps with the social service function. Informed by studies from He Jingshi [23] and Cai Wenbo et al. [24], these two functions are consolidated into a single output indicator termed Scientific Research & Social Service. Following Zhao Qingnian et al. [25], Liu Hu et al. [26], and Yi Ming et al. [27], the Number of Patents Granted (units) is selected as the output measure.

The specific indicator system is shown in **Table 1**. Furthermore, DEA models require that the number of DMUs be at least three times the sum of the number of input and output indicators; otherwise, the model's discriminatory power weakens [28]. This study utilizes 92 DMUs, 5 input indicators, and 2 output indicators, satisfying the DEA model's requirements for input-output indicators.

Table 1: Higher Education Resource Allocation Efficiency Evaluation Index System

Category	Level 1 indicator	Level 2 indicator	Unit
Input Indicators	Human Resources	Total Number of Full-time Faculty	persons
	Material Resources	Library Collection Size	thousand volumes
		Number of Higher Education Institutions	institutions
	Financial Resources	Education Expenditure	ten thousand yuan
		Scientific Expenditure (R&D Expenditure)	ten thousand yuan
Output Indicators	Talent Cultivation	Number of Graduates	persons
	Scientific Research & Social Service	Number of Patents Granted	units

2.3 Data Sources

Ensuring authenticity, authority, availability, and timeliness, this study utilizes input and output indicator data from a total of 92 cities at the prefecture level and above within the Five Major Economic Circles for the period 2018–2022. The cities included in each economic circle are defined according to the corresponding urban agglomeration development plans. Data sources include the China Statistical Yearbook, China Education Statistical Yearbook, China Statistical Yearbook on Education Expenditure, China City Statistical Yearbook, provincial and municipal statistical yearbooks, and the official websites of major universities.

3. Empirical Results and Analysis of Higher Education Resource Allocation Efficiency

Based on the panel data from 92 cities within the Five Major Economic Circles from 2018 to 2022, this study utilized DEAP 2.1 software to calculate their higher education resource allocation efficiency. The distribution of average efficiency scores is presented in Table 2. Overall, the average comprehensive technical efficiency (Crste) of these 92 cities ranges between 0.417 and 1, exhibiting a generally fluctuating trend. The level of higher education resource allocation efficiency is moderately high. However, 91.304% of the cities did not reach the efficiency frontier, indicating a significant gap between the input-output structure of higher education resources in the Five Major Economic Circles and the expected comprehensive benefits. This suggests that the management level of universities and their capacity for rational allocation of input factors still require further improvement.

Table 2: Distribution of Comprehensive Technical Efficiency (Crste) Average Scores by Range for 92 Cities in the Five Major Economic Circles (2018-2022)

Efficiency Average Range	Cities	City Share by Economic Circle
(0.4, 0.5]	Beijing, Shanghai	Beijing-Tianjin-Hebei: 50.000% Yangtze River Delta: 50.000%
(0.5, 0.6]	Zhoushan, Fuzhou (JX)	Yangtze River Delta: 50.000% Yangtze River Midstream: 50.000%
(0.6, 0.7]	Tianjin, Cangzhou, Handan, Yancheng, Anqing, Huanggang, Xiaogan, Yichang, Changde, Loudi, Yichun (JX), Shangrao, Ziyang	Beijing-Tianjin-Hebei: 23.077% Yangtze River Delta: 15.385% Yangtze River Midstream: 53.846% Chengdu-chongqing: 7.692%
(0.7, 0.8]	Chengde, Tangshan, Langfang, Wuxi, Suzhou, Zhenjiang, Hangzhou, Ningbo, Huzhou, Shaoxing, Chuzhou, Jiangmen, Huangshi, Ezhou, Jingmen, Zhuzhou, Yiyang, Jiujiang, Xinyu, Pingxiang, Luzhou, Yibin, Dazhou, Chongqing	Beijing-Tianjin-Hebei: 12.500% Yangtze River Delta: 33.333% Guangdong-hong Kong-Macao: 4.167% Yangtze River Midstream: 33.333% Chengdu-chongqing: 16.667%
(0.8, 0.9]	Zhangjiakou, Cangzhou, Nantong, Yangzhou, Taizhou (JS), Jiaxing, Jinhua, Tongling, Xuancheng, Huizhou, Xianning, Xiangyang, Yueyang, Hengyang, Mianyang, Suining	Beijing-Tianjin-Hebei: 12.500% Yangtze River Delta: 43.750% Guangdong-hong Kong-Macao: 6.250% Yangtze River Midstream: 25.000% Chengdu-chongqing: 12.500%
(0.9, 1]	Qinhuangdao, Baoding, Shijiazhuang, Xingtai, Nanjing, Changzhou, Taizhou (ZJ), Chizhou, Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Zhongshan, Zhaoqing, Wuhan, Jingzhou, Changsha, Xiangtan, Nanchang, Yingtan, Ji'an, Chengdu, Zigong, Deyang, Neijiang, Leshan, Nanchong, Meishan, Guangan, Ya'an	Beijing-Tianjin-Hebei: 12.903% Yangtze River Delta: 12.903% Guangdong-hong Kong-Macao: 22.581% Yangtze River Midstream: 22.581% Chengdu-chongqing: 29.032%

As shown in **Table 2**:

Cities with an average Crste below 0.7 are primarily concentrated in the Yangtze River Midstream region.

Cities with an average Crste between 0.7 and 0.9 are mainly located in Yangtze River Delta and Yangtze River Midstream regions.

Cities with an average Crste between 0.9 and 1 are predominantly found in the Chengdu-Chongqing, Guangdong-Hong Kong-Macao (GBA), and Yangtze River Midstream regions.

This data indicates substantial regional disparities in the efficiency of higher education resource allocation at the municipal level, with the Yangtze River Midstream region exhibiting particularly noticeable variations.

Guangdong-Hong Kong-Macao Greater Bay Area (GBA): The overall level of comprehensive technical efficiency (Crste) in the GBA is relatively high. However, only four cities – Shenzhen, Foshan, Dongguan, and Zhongshan – lie on the efficiency frontier. Huizhou (0.891), Jiangmen (0.732), and Zhaoqing (0.924) fall below the regional average (0.939). The reasons are multifaceted: the GBA boasts a high level of socio-economic development, strong aggregation of innovative elements, and distinctive characteristics in the higher education systems of Guangdong, Hong Kong, and Macao. Significant national policy support in recent years has further increased higher education investment in the region. Shenzhen benefits from rich higher education resources, including centrally-administered key universities under the "985", "211", and "Double First-Class" initiatives (e.g., Southern University of Science and Technology, Peking University Shenzhen Graduate School, Harbin Institute of Technology, Shenzhen), as well as Sino-foreign cooperative institutions (e.g., The Chinese University of Hong Kong, Shenzhen; Shenzhen MSU-BIT University). This results in substantial education funding, high research output efficiency, and strong internal university management. Foshan, Dongguan, and Zhongshan, while lacking centrally - administered key universities, possess strong higher vocational education under the "Double High Plan" policy, emphasizing "industry-education integration" and maintaining a relatively rational scale. In contrast, Huizhou, Jiangmen, and Zhaoqing have smaller higher education scales (e.g., in 2022: 5, 7, and 10 institutions respectively), with a higher proportion of private vocational colleges. Potential deficiencies in funding and faculty resources may contribute to their Crste inefficiency.

Chengdu-Chongqing Economic Circle: The overall Crste level ranks second among the circles. However, only Deyang and Ya'an lie on the efficiency frontier. Luzhou (0.751), Mianyang (0.881), Suining (0.837), Yibin (0.787), Dazhou (0.795), Ziyang (0.628), and Chongqing (0.756) fall below the regional average (0.884). Deyang and Ya'an achieve high Crste despite having fewer universities, likely due to a relatively rational scale, effective internal university management, and efficient utilization of education funding to cultivate applied technical talents needed nationally. Conversely, universities in Luzhou, Mianyang, Suining, Yibin, Dazhou, and Ziyang are predominantly newer vocational institutions, many private, lacking "Double High Plan" support and starting later. Potential shortcomings in funding, faculty, and internal management likely contribute to their inefficiency. Chongqing, with 70 institutions by 2022, including comprehensive "Double First-Class" universities (e.g., Chongqing University, Southwest University) and "Double High Plan" vocational colleges, shows low Crste. This inefficiency may stem from output lag. Following the 2021 national action plans ("Optimizing and Enhancing Education Function Layout," "Accelerating Integrated Development of Vocational Education," "Promoting Connotative Development of Higher Education"), Chongqing received increased higher education investment. However, the outputs of talent cultivation and technology transfer often require longer cycles. With the study ending in 2022, the data reflects Chongqing as inefficient.

Yangtze River Delta Region: The overall Crste level ranks third. However, the situation by city is concerning, with no city reaching the efficiency frontier. Shanghai (0.459), Wuxi (0.789), Suzhou (0.769), Nantong (0.801), Yancheng (0.692), Zhenjiang (0.771), Hangzhou (0.709), Ningbo (0.739), Jiaxing (0.803), Huzhou (0.751), Shaoxing (0.777), Zhoushan (0.552), Wenzhou (0.803), Ma'anshan (0.789), Anqing (0.687), and Chuzhou (0.734) all fall below the overall Five Circles average (0.822). Cities like Yancheng, Huzhou, and Zhoushan may suffer from insufficient university scale and weak internal management. They need to actively respond to the national strategy for independent cultivation of applied talents by expanding vocational institutions and innovating management systems to match "connotative development." For cities like Shanghai, Hangzhou, and Suzhou – located in the affluent eastern coastal area with high investment in education and R&D, and numerous high-quality universities – the low efficiency may result from input redundancy in higher education and insufficient talent/research output potentially linked to educational involution. Additionally, internal macro-level reforms within universities are needed to enhance management efficiency and better align with the substantial inputs.

Yangtze River Midstream Region: The overall Crste level ranks fourth. Only Nanchang lies on the efficiency frontier. Huangshi (0.708), Ezhou (0.758), Huanggang (0.661), Xiaogan (0.666), Xianning (0.808), Yichang (0.667), Jingmen (0.753), Zhuzhou (0.797), Yueyang (0.808), Yiyang (0.753), Changde (0.682), Loudi (0.659), Jiujiang (0.721), Xinyu (0.717), Yichun (0.688), Pingxiang (0.720), Shangrao (0.652), and Fuzhou (0.572) fall below the overall Five Circles average (0.822). Nanchang's relatively rational university scale and effective internal management enable efficient resource allocation. Cities like Huangshi, Huanggang, and Jingmen likely suffer from insufficient higher education scale and resource input. For cities like Xianning, Jingzhou (implied in context), and Zhuzhou with moderate scales, inefficiency may stem from low internal management efficiency and suboptimal input allocation, leading to insufficient talent and research output.

Beijing-Tianjin-Hebei Region: The overall Crste level is relatively low. Only Shijiazhuang lies on the efficiency frontier. Beijing (0.417), Tianjin (0.573), Chengde (0.704), Tangshan (0.818), Hengshui (0.679), Langfang (0.788), and Handan (0.692) fall below the overall Five Circles average (0.822). Shijiazhuang demonstrates a rational university scale, effective management, and high input-allocation efficiency. Beijing and Tianjin, benefiting from national policies, host numerous comprehensive "985", "211", "Double First-Class" universities and "Double High Plan" vocational colleges. Their inefficiency likely arises from input redundancy and insufficient talent/research output, potentially exacerbated by educational involution. By 2022, Chengde and Hengshui had only 6 and 2 institutions respectively; their limited scale and potentially weak management constrain efficiency gains. Tangshan and Langfang, each with 12 institutions (moderate scale by 2022), show inefficiency possibly due to insufficient funding input and internal management inefficiencies hindering talent cultivation and technology transfer.

4. Conclusions and Recommendations

4.1 Data Sources

Overall Low Efficiency with Regional Disparities: The overall efficiency of higher education resource allocation in the Five Major Economic Circles remains relatively low. The Beijing-Tianjin-Hebei region exhibits the most severe inefficiency, while the Yangtze River Midstream region demonstrates significant internal regional disparities.

Role of Pure Technical Efficiency: While technological progress across the circles generally maintained a high level and scale efficiency achieved a state of dynamic balance, the decline in pure technical efficiency emerged as the primary cause of the low overall resource allocation efficiency.

4.2 Recommendations

Establish a Rational and Scientific Higher Education Resource Investment System to Promote High-Quality Talent and Research Output: Socio-economic development levels vary significantly across the Five Major Economic Circles. Cities like Cangzhou, Nantong, and Zhaoqing face insufficient resource investment to meet growing educational demands, constraining educational development. Conversely, economically advanced cities like Beijing, Shanghai, and Hangzhou exhibit a mismatch between substantial government funding inputs and outputs; resources are not always effectively converted into tangible results, leading to input redundancy and underutilization. This highlights an uneven and regionally disparate layout of resource investment. Therefore, governments should:

Optimize Input-Output Efficiency: Based on scientific assessments, optimize resource allocation efficiency across regions within the circles.

Support Less Developed Regions: Broaden funding sources, increase resource investment, and attract high-level talent in regions with slower socio-economic development. Actively respond to the national strategy for independent cultivation of applied talents by expanding the number of higher vocational institutions.

Refine Spending in Developed Regions: In rapidly developing regions, rationally arrange education expenditures based on actual conditions. Implement performance management mechanisms for higher education fiscal funds to comprehensively improve the efficiency of fund allocation and utilization, aligning with universities' pursuit of connotative development.

Align with Market Demands: Establish a sound faculty and administrative system guided by market needs. Cultivate specialized, high-quality professionals from the perspective of fulfilling market talent supply and promoting socio-economic development.

Leverage Local Advantageous Disciplines and Higher Education's Spatial Spillover Effects to Promote Educational Equity: The 92 cities within the Five Major Economic Circles exhibit varying levels of economic, social, and technological development, leading to heterogeneity in the quantity, scale, and quality of higher education resources. Economically powerful and geographically advantaged cities like Beijing, Hangzhou, and Shenzhen, bolstered by national policies like "Double First-Class" and the "Double High Plan," tend to concentrate resources in specific advantageous disciplines, further amplifying resource accumulation through the "Matthew Effect". Meanwhile, cities with lagging socio-economic development, such as Yiyang, Pingxiang, and Dazhou, exhibit lower resource allocation efficiency. To address this:

Government Action: Integrate considerations of local socio-economic development, the existing stock and potential of higher education resources, and changing market demands. While coordinating national university development, prioritize allocating human, financial, and material resources to advantageous disciplines in underdeveloped regions. This fosters spatial agglomeration effects for higher education resources, creating a positive interaction with local socio-economic development and maximizing allocation efficiency.

University Collaboration: Recognize that research activities across universities within the circles are not isolated but interdependent. Large and medium-sized cities with strong development momentum and higher resource allocation efficiency should serve as models, assisting the development of surrounding smaller cities. Smaller cities should actively learn from their experiences to improve their own economic development levels. Universities of different types within the same circle should enhance information exchange, research collaboration, and facilitate the flow of faculty and research talent across disciplines.

Implement Internal Macro-Management System Reform and Innovation within Universities, and Efficiently Coordinate External Advanced Scientific Resources to Adapt to "Connotative Development" in the New Era: As crucial units for research output, universities play a vital role in China's scientific innovation. The empirical analysis identified low pure technical efficiency as the main reason for inefficient resource allocation. The suboptimal input-output efficiency remains a significant challenge in fostering top-notch innovative talent and driving research innovation. Therefore:

Internal Reform: Universities in cities like Huzhou, Jiangmen, and Mianyang need to innovate their internal macro-management systems to enhance management capabilities and efficiency.

Technology Absorption & Conversion: While learning and introducing advanced teaching management technologies and scientific techniques, universities should focus on shortening the technology absorption cycle. This transforms technology introduction and R&D into an internal driving force for reforming the teaching and management system.

External Coordination: Universities must proactively and efficiently coordinate and integrate external advanced scientific and technological resources. This involves establishing robust mechanisms for collaboration with industry, research institutes, and other universities to access and leverage cutting-edge knowledge and tools effectively.

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