

The Impact of Higher Education Enrollment on Per Capita GDP in the Yangtze River Delta: An Analysis Based on BCC-DEA and Spatial Econometric Models

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Abstract

The Yangtze River Delta (YRD) is a key driver of China's economic growth, with higher education playing a critical role in fostering regional economic development. This study uses the BCC-DEA model and spatial econometric methods with 2022 data to evaluate the efficiency of regular higher education enrollment in contributing to per capita GDP and explores its spatial distribution. The results reveal significant regional disparities in resource allocation, with some cities being DEA-efficient, such as Zhoushan, Wuxi, and Xuancheng ($TE = 1$), while others exhibit inefficiencies, including Shanghai ($TE = 0.15$; $SE = 0.338$) and Hefei ($TE = 0.032$; $SE = 0.934$). Spatial correlation between higher education resources and per capita GDP is weak, with Moran's $I = -0.073$, and OLS regression shows a mismatch between educational resources and economic development, with the coefficient of enrollment (-0.017 , $p = 0.694$) and low explanatory power ($R^2 = 0.094$; adjusted $R^2 = -0.359$). This study provides theoretical insights and policy recommendations for optimizing resource allocation and promoting coordinated development between higher education and the economy in the YRD region.

Keywords: Yangtze river delta, Student enrollment, Per capita GDP, BCC-DEA, Spatial econometric analysis

Introduction

The Yangtze River Delta region, comprising Shanghai, Jiangsu, Zhejiang, and Anhui provinces, is a crucial engine of China's economic development and has long played a pivotal role in the nation's overall economic and social progress. Known for its large economic scale and solid industrial foundation, the region has also leveraged its strong innovation-driven capacity and high degree of openness to play an essential role in advancing national reform and opening-up, as well as enhancing the country's comprehensive national strength (Ying, 2021). On November 30, 2023, President Xi Jinping chaired a symposium in Shanghai to promote the deeper integration of the Yangtze River Delta and delivered an important speech. He emphasized that advancing the integration of the region is of significant importance for establishing a new development pattern, driving high-quality growth, and achieving Chinese-style modernization and national rejuvenation. He called for a coordinated approach to advancing scientific and technological innovation, industrial innovation, ecological protection, and economic development, with the goals of "integration" and "high quality," to serve as a model and guide for high-quality development across the country.

Education, as a fundamental driver of economic development, plays an increasingly critical role in the integration and high-quality development of the Yangtze River Delta region. In particular, higher education plays an irreplaceable role in improving human capital quality, driving technological innovation, and promoting industrial upgrading (Liang Chen, 2024). The Yangtze River Delta region hosts some of the country's leading higher education resources, including universities and research institutions with international influence, which provide strong talent support and intellectual backing for the regional economy (Jinling Gao, 2024; Wei Bu, 2022). However, significant disparities in the allocation and utilization efficiency of higher education resources within the region persist, and the uneven distribution of economic development levels and educational resources among cities exacerbates this issue. Therefore, studying the impact of the number of university students in the Yangtze River Delta on regional economic development, analyzing the spatial distribution characteristics and efficiency of higher education resources, and exploring their potential mechanisms for economic development is of great theoretical value and practical significance. This research not only deepens the understanding of the synergy between education and economic development, but also provides scientific evidence for optimizing regional educational policies, improving resource allocation efficiency, and promoting economic integration.

A substantial body of research has explored the mechanisms through which education influences economic growth globally. The general consensus is that higher education significantly promotes regional economic development by enhancing human capital, facilitating knowledge spillovers, and boosting technological innovation capacity (Barro & Sala-i-Martin, 2004). For instance, the experiences of European and American countries demonstrate that higher education not only supplies the labor market with highly skilled talent, but also drives regional industrial upgrading through university-industry-government collaboration. In developing countries, the expansion and investment in higher education also have a significant positive impact on economic growth, although the intensity and mechanisms of this impact may vary depending on the stage of regional development and the distribution of educational resources (Jaffry, 2022).

In China, as higher education rapidly shifted from an elite model to a mass model, its role in promoting regional economic development has garnered significant attention. Recent studies have shown that the positive effects of education on per capita GDP are particularly pronounced in the eastern coastal regions, and there is a clear spatial heterogeneity between

educational investment and economic growth (Dexiang Zhang, 2024). However, existing research primarily focuses on national or provincial levels, and studies specifically examining the distribution and utilization efficiency of higher education resources within particular regions, such as the Yangtze River Delta, remain insufficient. In particular, there is a lack of comprehensive analysis of the interaction between education and economic development from the perspectives of spatial econometrics and efficiency evaluation.

In the context of the important relationship between economic development and the allocation of higher education resources in the Yangtze River Delta region, this study explores the relationship between the number of university students and per capita GDP, focusing on the following core questions: First, does higher education significantly influence the per capita GDP of cities in the Yangtze River Delta? Second, what are the spatial distribution characteristics and efficiency of higher education in the region? Third, what policy implications can be drawn from the efficiency of higher education resource allocation for regional economic development? To address these questions, this study employs Data Envelopment Analysis (DEA) to assess the resource utilization efficiency of the number of university students in relation to per capita GDP and identifies the spatial distribution characteristics of educational efficiency. Additionally, spatial autocorrelation models (such as Moran's I and LISA cluster analysis) are used to reveal the spatial dependence and regional agglomeration effects between higher education and per capita GDP. Furthermore, a spatial two-stage ordinary least squares (OLS) regression analysis is conducted to empirically assess the quantitative impact of higher education on per capita GDP. This research provides scientific evidence and policy recommendations for optimizing the allocation of higher education resources and promoting the coordinated economic development of the Yangtze River Delta region.

Methodology

1. Data Sources

The data used in this study are sourced from the officially published and publicly available Shanghai Statistical Yearbook, Jiangsu Statistical Yearbook, Anhui Statistical Yearbook, and Zhejiang Statistical Yearbook (2023 edition). The data are from the end of 2022 and include indicators related to higher education and economic development in the Yangtze River Delta region. This study selects 40 prefecture-level cities and 1 directly administered municipality (Shanghai) from the three provinces and one municipality (Jiangsu, Zhejiang, Anhui, and Shanghai) in the Yangtze River Delta as the Decision Making Units (DMUs). The key data used in this study include the number of university students and per capita GDP for each city.

The number of university students is defined as the total number of full-time students enrolled in all higher education institutions offering degree programs in a prefecture-level city. These institutions include full-time universities, independent colleges, higher vocational schools, and other higher education establishments that meet national standards for establishment and approval procedures. This variable reflects the scale of higher education resources in the city and is one of the key indicators of educational development. The number of university students not only represents the capacity for educational resource delivery but also indirectly reflects the supply and demand conditions of higher education within the region (Qian & Smyth, 2008). By quantifying educational resources at the prefecture level, this indicator provides a scientific basis for analyzing the impact of higher education on regional economic growth.

Per capita GDP is a core indicator used to measure the level of regional economic development. It is defined as the ratio of the total value of final output produced by all resident units in a certain period (regional GDP) to the total population of the region. Per capita GDP reflects both the overall efficiency of economic activities in the prefecture and the average economic welfare level of its residents. As a research variable, per capita GDP directly reflects the quality of regional economic development and provides important evidence for examining the contribution of higher education resources to economic growth (Barro, 2013).

2. BCC-DEA Model

Data Envelopment Analysis (DEA) is a non-parametric method based on mathematical programming, primarily used to assess the relative efficiency of Decision Making Units (DMUs) in environments with multiple inputs and outputs. This method was first introduced by Charnes, Cooper and Rhodes (1978) with the CCR model, which assumes that all DMUs exhibit constant returns to scale (Charnes et al., 1978). Later, Banker et al. (1984) introduced the BCC model, relaxing the constant returns to scale assumption of the CCR model and allowing different DMUs to exhibit varying returns to scale. The BCC model is based on four basic axioms of the production possibility set and incorporates Shephard's distance function, enabling it to simultaneously measure both technical efficiency and scale efficiency of the DMUs.

This study employs the BCC-DEA model in its product form for efficiency evaluation, primarily because this model can flexibly handle non-linear relationships between inputs and outputs and supports the variable returns to scale (VRS) assumption. This is especially suitable for the Yangtze River Delta region, where there are significant differences in scale and resource distribution among prefecture-level cities. In this research, the DEA-BCC model is used to analyze the impact of university student enrollment (educational resources) on per capita GDP (economic output) efficiency in 41 cities in the Yangtze River Delta. Specifically, the prefecture-level cities are treated as DMUs, with the number of university students as the input variable and per capita GDP as the output variable. By constructing an efficiency frontier based on these input and output variables, DEA can reveal the differences in efficiency regarding higher education resource allocation and economic output across different cities, providing a scientific basis for optimizing the allocation of regional higher education resources.

The formulas used in this study are based on the descriptions by Gao and Huang (2011) on page 34 of Management Performance Evaluation: Data Envelopment Analysis (Qiang Gao, 2011), which provide a detailed explanation of the application of the product form model in DEA. The specific formula is as follows:

$$\begin{aligned}
 & \text{Max } h_k = \sum_{r=1}^s u_r Y_{rk} - u_0 \\
 & \text{Subject to} \\
 & \sum_{i=1}^m v_i X_{ik} = 1 \\
 & \sum_{r=1}^s u_r Y_{rj} - \sum_{i=1}^m v_i X_{ij} - u_0 \leq 0, j = 1, 2, \dots, n \\
 & u_r, v_i \geq 0, r = 1, \dots, s, i = 1, \dots, m \\
 & u_0 \text{ No positive or negative restrictions}
 \end{aligned} \tag{1}$$

3. Spatial Analysis

Building on the previous DEA model analysis, this study further incorporates spatial econometric methods to explore the spatial relationship between university enrollment and per capita GDP in the Yangtze River Delta. Spatial econometrics is a key tool for studying the spatial distribution and interrelationships of geographic phenomena, aiming to reveal the interdependence and spatial effects between spatial units (Anselin, 1988). Based on Anselin's (1988) theoretical framework, this study uses the Datav.GeoAtlas data visualization platform to download spatial map resources of the Yangtze River Delta region and utilizes the GeoDa spatial data analysis software for spatial modeling and visualization of relevant variables. This allows for the identification of spatial dependence and spillover effects between university enrollment and per capita GDP.

The specific analytical process includes the following three steps:

Step 1: Select Anhui, Jiangsu, Zhejiang, and Shanghai as the four provincial-level administrative units for spatial autocorrelation analysis. Spatial autocorrelation refers to the correlation between a geographic phenomenon or attribute in a given spatial unit and the same phenomenon or attribute in neighboring units. Spatial autocorrelation can be divided into global autocorrelation and local autocorrelation.

Global autocorrelation describes the distribution pattern of a phenomenon or attribute across the entire study area, revealing whether spatial clustering exists. The calculation formula for global autocorrelation is as follows:

$$I = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n w_{ij}} \cdot \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2} \quad (2)$$

Local autocorrelation further reveals specific clustering areas and can identify spatial associations within local regions. The calculation formula for local autocorrelation is as follows:

$$LISA_i = (x_i - \bar{x}) \sum_{j=1}^n w_{ij} (x_j - \bar{x}) \quad (3)$$

Where:

I represents Moran's I Index;

n is the number of spatial units;

x_i and x_j represent the attribute values of regions i and j, respectively;

$\bar{x}$ is the global mean;

W_{ij} is the spatial weight matrix, indicating the spatial adjacency relationship between regions i and j;

$LISA_i$ represents the Local Moran's I Index (Local Indicators of Spatial Association).

Step 2: By plotting the bivariate Moran's I map, BILISA clustering map, and significance distribution map, this study reveals the spatial correlation characteristics between university enrollment and per capita GDP. The bivariate Moran's I map reflects the degree of spatial association between the two variables, determining whether there is a positive or negative spatial correlation. The BILISA clustering map further identifies specific spatial clustering types, including “high-high clusters” (both university enrollment and per capita GDP are high), “low-low clusters” (both are low), “high-low clusters” (high university enrollment

but low per capita GDP), and “low-high clusters” (low university enrollment but high per capita GDP), uncovering the spatial imbalance between regions. The significance distribution map shows the significant areas of local spatial autocorrelation, identifying the statistically significant spatial association regions and further revealing the spatial distribution differences between regions.

Finally, ordinary least squares (OLS) regression analysis is used to model the relationship between university enrollment and per capita GDP, generating a regression report to explore their correlation and significance in the spatial dimension. On this basis, the analysis is further refined to each provincial-level administrative unit, examining the spatial correlation between university enrollment and per capita GDP by province and deeply revealing the geographical spatial interactions between the two variables.

Results

1.Static Analysis: The Impact of Higher Education on Per Capita GDP Efficiency

The data used in this study are based on statistical figures from the end of 2022, and thus, the analysis in this section is a static analysis. By importing the statistical data on university enrollment (input variable) and per capita GDP (output variable) from 41 cities in the Yangtze River Delta into the DEAP 2.1 analysis software, the static efficiency results for each prefecture-level city were calculated, as shown in Table 1.

Table 1 Static Efficiency Analysis of Higher Education's Impact on Per Capita GDP in the Yangtze River Delta Region

Item	E	SE	θ	SRC	Type	Item	TE	SE	θ	SRC	Type
Shanghai	0.15	0.338	0.051	1.076	DRS	Ma'anshan	0.262	0.913	0.239	0.695	IRS
Hangzhou	0.049	0.98	0.048	0.913	IRS	Wuhu	0.132	0.925	0.122	0.728	IRS
Ningbo	0.144	0.996	0.143	0.981	IRS	Xuancheng	1	0.798	0.798	0.46	IRS
Wenzhou	0.108	0.821	0.089	0.497	IRS	Tongling	0.363	0.852	0.31	0.555	IRS
Jiaxing	0.312	0.926	0.288	0.729	IRS	Chizhou	0.373	0.814	0.303	0.485	IRS
Huzhou	0.5	0.906	0.453	0.676	IRS	Anqing	0.248	0.69	0.171	0.398	IRS
Shaoxing	0.17	0.956	0.162	0.823	IRS	Huangshan	0.452	0.784	0.354	0.452	IRS
Jinhua	0.143	0.802	0.114	0.467	IRS	Nanjing	0.081	0.357	0.029	1.07	DRS
Quzhou	0.896	0.836	0.749	0.524	IRS	Wuxi	1	0.187	0.187	1.187	DRS
Zhoushan	1	1	1	1	—	Xuzhou	0.09	0.855	0.077	0.561	IRS
Taizhou	0.375	0.846	0.317	0.542	IRS	Changzhou	0.51	0.368	0.187	1.066	DRS
Lishui	0.362	0.756	0.273	0.436	IRS	Suzhou (in Jiangsu Province)	0.391	0.263	0.103	1.113	DRS
Hefei	0.032	0.934	0.03	0.753	IRS	Nantong	0.162	0.971	0.158	0.88	IRS
Huaibei	0.322	0.689	0.222	0.397	IRS	Lianyungang	0.257	0.834	0.214	0.521	IRS
Bozhou	0.67	0.439	0.294	0.253	IRS	Huai'an	0.181	0.884	0.16	0.623	IRS
Suzhou (in Anhui Province)	0.381	0.435	0.165	0.251	IRS	Yancheng	0.238	0.888	0.212	0.632	IRS
Bengbu	0.2	0.63	0.126	0.363	IRS	Yangzhou	0.194	0.984	0.191	0.928	IRS
Fuyang	0.247	0.411	0.102	0.237	IRS	Zhenjiang	0.183	0.985	0.18	0.932	IRS
Huainan	0.165	0.527	0.087	0.304	IRS	Taizhou	0.313	0.963	0.302	0.849	IRS
Chuzhou	0.266	0.843	0.224	0.537	IRS	Suqian	0.514	0.818	0.421	0.493	IRS
Lu'an	0.272	0.474	0.129	0.273	IRS						

NOTE:

TE: Technical Efficiency

SE: Scale Efficiency

θ: Comprehensive Efficiency

SRC : Scale Return Coefficient

IRS: Increasing Returns to Scale

DRS: Decreasing Returns to Scale

—: No scale return identified

In Table 1, the product of technical efficiency (TE) and scale efficiency (SE) equals the overall efficiency (θ), which reflects the overall efficiency performance of the decision-making units (DMUs). In terms of scale returns, DRS indicates decreasing returns to scale, while IRS indicates increasing returns to scale. Table 1 presents the static results from the model, revealing the impact of higher education resource allocation on regional economic output from three dimensions: technical efficiency, scale efficiency, and returns to scale. These results provide a foundational basis for analyzing the efficiency disparities of higher education within the region.

According to the DEA analysis results in Table 1, cities with a technical efficiency (TE) of 1 are considered DEA efficient units (effective DMUs), such as Zhoushan, Wuxi, and Xuancheng. These cities have achieved optimal allocation of higher education resources and are able to fully utilize educational investments to maximize regional economic output. For example, Zhoushan's technical efficiency (TE = 1) and scale efficiency (SE = 1) both reach the efficiency frontier, indicating that its higher education resource allocation is perfect, with no restrictions from scale returns (SRC = 1). Similarly, Wuxi not only performs excellently in technical efficiency (TE = 1), but its scale returns coefficient (SRC = 1.187) reflects that further expansion of its educational resources would yield higher output. These efficient units provide valuable insights for optimizing educational resource allocation in other cities.

In contrast, DEA inefficient units (inefficient DMUs) such as Shanghai and Hefei exhibit significant issues with resource allocation efficiency. For example, Shanghai's technical efficiency is only 0.15, and its scale efficiency is 0.338, showing decreasing returns to scale (DRS, SRC = 1.076), indicating that its educational resource input has become excessive, diminishing the marginal output of resource utilization. Similarly, Hefei's technical efficiency (TE = 0.032) is at its lowest level, indicating extremely low efficiency in the use of higher education resources. However, its scale efficiency (SE = 0.934) is relatively high, suggesting that it could improve overall efficiency by reasonably expanding the scale of educational resource input.

2. Interprovincial Spatial Analysis Results

In the spatial analysis, this study uses the Queen contiguity weight and sets the order to 1 (Order 1) to construct the spatial weight matrix. This method is based on the shared boundary or vertex relationship between spatial units, assuming that two spatial units are adjacent if they share a common boundary segment or vertex. By setting the weight for the direct adjacency relationship among the four provincial-level administrative units in the Yangtze River Delta (Anhui, Jiangsu, Zhejiang, and Shanghai), the order 1 setting only considers the spatial correlation between adjacent units, excluding higher-order spatial interactions, which makes the spatial weight matrix more intuitive and concise. The research results are shown in Figure 1.

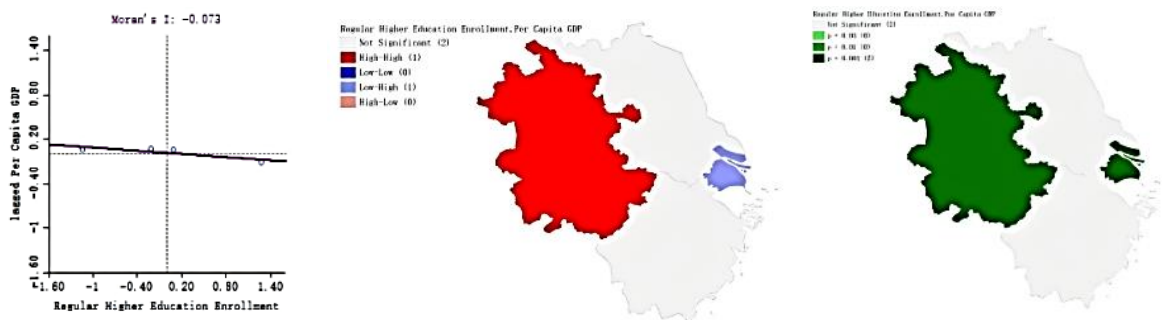


Figure 1 Interprovincial Spatial Analysis Results in the Yangtze River Delta Region

Figure 1's Moran's I map shows that the spatial correlation between the number of university students and per capita GDP in the Yangtze River Delta is weak, with a specific Moran's I value of -0.073, indicating a slight negative correlation. The trend line in the scatter plot is slightly downward sloping, further confirming the negative correlation between the two variables. However, the data points are widely dispersed, suggesting a weak overall spatial association. This indicates that the impact of the number of university students on regional economic development, specifically on per capita GDP, is not spatially balanced and the overall effect is weak.

In the BiLISA clustering view, some areas of Anhui Province are identified as high-high clusters (red areas), meaning both the number of university students and per capita GDP are high, with significant positive spatial correlation. In contrast, Shanghai is characterized as a low-high cluster (blue area), where the number of university students is relatively low, but the surrounding areas have higher per capita GDP, indicating significant spatial correlation between Shanghai and its neighboring high-value areas. Other regions do not exhibit clear spatial clustering features and are categorized as non-significant areas (gray areas).

In the BiLISA significance map, some areas in Anhui Province and Shanghai passed the statistical significance test at a significance level of $p \leq 0.001$ (dark green areas), indicating that the spatial correlation between the number of university students and per capita GDP is significant in these regions. Other areas in the Yangtze River Delta did not pass the significance test (gray areas), showing an uneven spatial correlation between regions. Therefore, from a spatial perspective, the relationship between the number of university students and per capita GDP shows significant regional differences, further revealing the presence of spatial dependence and spillover effects between regions.

To further explore the relationship between the number of university students and per capita GDP in the Yangtze River Delta, this study conducted an Ordinary Least Squares (OLS) regression analysis for verification. The specific form of the regression equation is as follows:

$$\text{Per Capita GDP} = 154157 - 0.0169028 \times \text{Regular Higher Education Enrollment}$$

Table 2 OLS Regression Results for the Number of University Students and Per Capita GDP in the Yangtze River Delta Region

Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	154157	60949.3	2.52926	0.12717
Regular Higher Education Enrollment	-0.0169028	0.0371553	-0.454922	0.69377

From the specific regression results in Table 2, the effect of the number of university students on per capita GDP is not significant (coefficient = -0.0169, $p = 0.69377$), which is consistent with the previous Moran's I analysis results. Furthermore, the explanatory power of the model is weak, with an R^2 of 0.0937 and an adjusted R^2 of -0.3593. The F-statistic did not pass the significance test ($p = 0.6938$), indicating a poor overall model fit.

Further regression diagnostics show that there is no multicollinearity issue, with the multicollinearity condition number being 4.448286, which falls within a reasonable range. Based on the results of both the OLS regression and spatial autocorrelation analysis, it can be concluded that the relationship between the number of university students and per capita GDP is statistically weak and exhibits regional heterogeneity. This provides the necessary theoretical support and data foundation for subsequent in-depth spatial econometric model analysis.

2.1 Spatial Analysis Results for Anhui Province

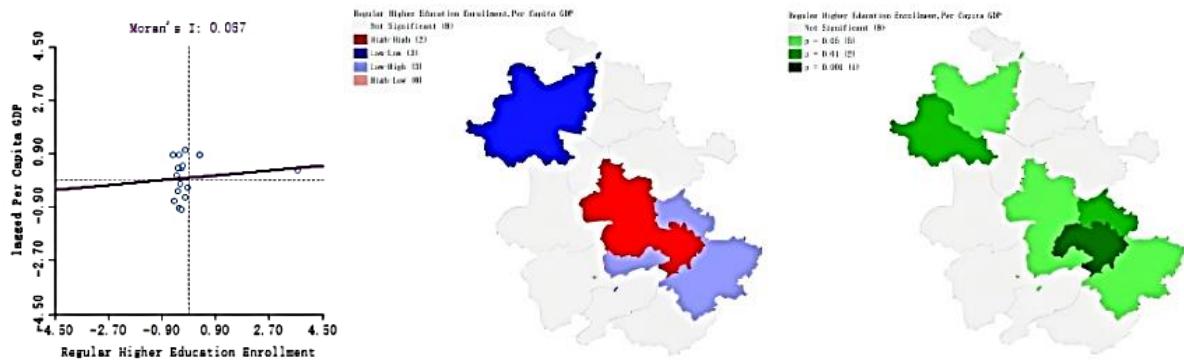


Figure 2 Spatial Analysis Results for Anhui Province's Enrollment and Per Capita GDP

The Moran's I index on the far left of Figure 2 is 0.087, indicating a weak positive spatial autocorrelation between the number of enrolled students in Anhui Province's higher education institutions and per capita GDP, though the overall correlation is not significant, and the spatial distribution appears relatively dispersed.

The middle section, which analyzes local spatial autocorrelation, reveals significant regional differences within Anhui Province:

The northwestern region (Fuyang, Bengbu, and Huaibei cities) exhibits a low-low clustering phenomenon, indicating that these areas have both low enrollment numbers and low per capita GDP.

The central region (Hefei and Wuhu cities) shows a high-high clustering, reflecting these cities' relatively rich educational resources and high economic development levels.

The southern region (Tongling, Ma'anshan, and Xuancheng cities) presents a low-high clustering phenomenon, indicating that these areas have fewer enrolled students but higher per capita GDP.

The significance distribution map on the far right of Figure 2 shows that most regions in Anhui Province do not have statistically significant spatial autocorrelation, indicating that the spatial coupling relationship between the number of enrolled students and per capita GDP is not significant. Only Wuhu City in the southern part of the province demonstrates significant spatial autocorrelation. This suggests that, overall, Anhui Province has not yet formed a significant spatial agglomeration effect, but there are noticeable spatial disparities between local regions, reflecting the uneven spatial distribution of educational resources and economic development.

2.2 Spatial Analysis Results of Jiangsu Province

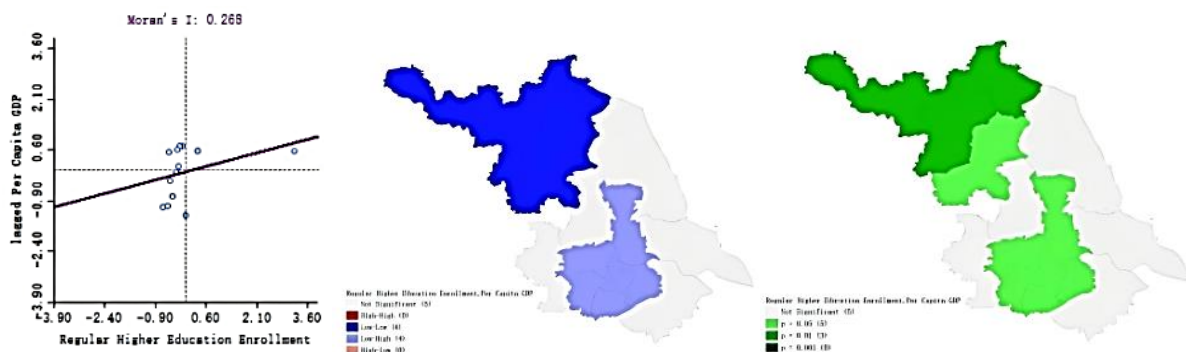


Figure 3 Spatial Analysis Results of Higher Education Enrolled Students and Per Capita GDP in Jiangsu Province

The leftmost Moran's I value is 0.268, indicating a weak but significant positive spatial autocorrelation between the number of enrolled students in higher education and per capita GDP in Jiangsu Province, with a certain clustering effect observed across regions. The middle local spatial autocorrelation analysis shows that the northern regions of Jiangsu Province (Xu Zhou, Lianyungang, Huai'an, and Suqian) exhibit a low-low cluster, meaning these areas have both lower numbers of enrolled students and lower per capita GDP. The southern regions (Zhenjiang, Changzhou, Wuxi) and the central region of Taizhou display a low-high cluster, indicating that these areas have higher per capita GDP but fewer enrolled students. Additionally, some regions do not show significant spatial clustering, reflecting spatial distribution differences.

The rightmost significance distribution map further reveals the spatial correlation characteristics of higher education enrolled students and per capita GDP in Jiangsu Province: The northern areas show significant spatial autocorrelation, while the southern and some central regions do not reach statistical significance. This indicates that while there is a clear spatial coupling between the number of enrolled students in higher education and per capita GDP in Jiangsu Province, a north-south difference exists. The northern regions, where educational resources and economic development are lagging, require increased investment in education resources to promote coordinated and balanced development of regional economy and higher education.

2.3 Zhejiang Province Spatial Analysis Results

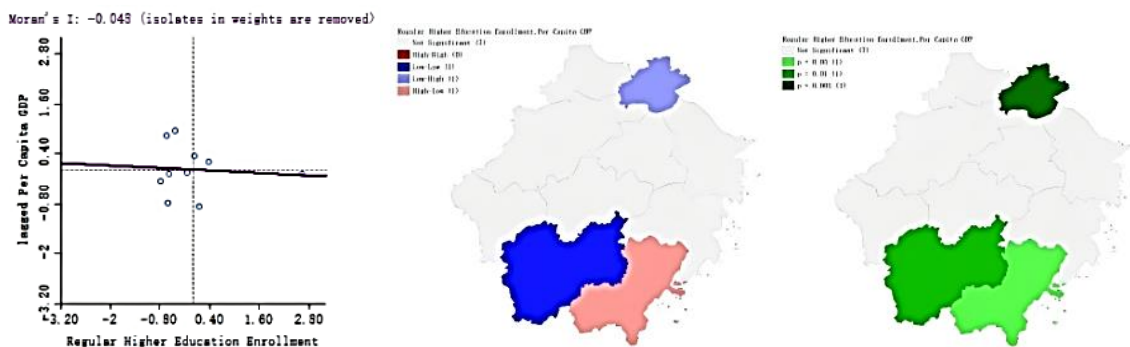


Figure 4 Spatial Analysis Results of Higher Education Enrolled Students and Per Capita GDP in Zhejiang Province

The leftmost Moran's I value is - 0. 048, indicating a weak negative spatial autocorrelation between the number of enrolled students in higher education and per capita GDP in Zhejiang Province, and overall, it is not significant. This suggests that the spatial distribution of enrolled students and per capita GDP is highly dispersed, with no apparent spatial clustering characteristics.

The middle local spatial autocorrelation analysis shows that the southern part of Zhejiang Province, particularly Wenzhou City, exhibits a high-low cluster, indicating that this area has a higher number of enrolled students but lower per capita GDP. The southwestern region, represented by Lishui City, displays a low-low cluster, reflecting that both enrolled students and per capita GDP are relatively low, suggesting spatial disadvantage clustering. The northern city of Jiaxing shows a low-high cluster, meaning it has fewer enrolled students but higher per capita GDP. In addition, most areas in the northern part of the province show no significant spatial autocorrelation, indicating that the spatial distribution of enrolled students and per capita GDP in these regions does not exhibit significant spatial correlation.

The rightmost significance distribution map further shows that the spatial autocorrelation in some southern areas is significant, while the majority of northern and central regions do not reach statistical significance. This indicates that the spatial correlation between the number of enrolled students and per capita GDP in Zhejiang Province is weak, with uneven regional distribution. Some areas exhibit low-level clustering. Overall, Zhejiang Province needs to optimize the allocation of higher education resources, improve educational investment and economic development in the southern and southwestern regions, to promote coordinated and balanced development of regional education and economy.

Discussions

1. Comparison of Theoretical Expectations and Actual Results

Traditional economic growth theories suggest that an increase in the number of enrolled students in higher education represents the accumulation of human capital, and as human capital is a crucial driver of economic growth, it should, in principle, have a significant positive correlation with regional GDP per capita (Lucas, 1988). However, the actual results of this study did not fully validate this expectation in the Yangtze River Delta region. According to the spatial analysis using Moran's I index, the overall region (with a value of -0.073) and Zhejiang Province (with a value of -0.048) showed a negative correlation, while Anhui Province (0.087) exhibited a weak positive correlation, though not significant. Jiangsu Province, although showing a certain degree of positive correlation (Moran's I = 0.268), still had a correlation strength lower than theoretical expectations. This phenomenon indicates that an increase in the number of enrolled students in higher education does not necessarily translate into a significant improvement in regional economic performance, reflecting potential issues in the efficiency of higher education resource utilization, the alignment of human capital with industry needs, and other factors, which warrant further investigation.

2. DEA Efficiency Analysis and the Current State of Higher Education Resource Utilization

Based on the results of the Data Envelopment Analysis (DEA) model, many cities show low technical efficiency (TE), scale efficiency (SE), and overall efficiency (θ), indicating that there are inefficiencies in the allocation and utilization of higher education resources. For example, Shanghai's technical efficiency is only 0.15, and its overall efficiency (θ) is also low, suggesting that the current resources are not being fully utilized and are unable to effectively drive economic growth. Moreover, an increase in the number of enrolled students does not necessarily lead to the accumulation of high-quality human capital, especially in cases where resource allocation is uneven and there are regional disparities in educational quality, making it difficult for higher education resources to reach their potential.

It is noteworthy that some cities exhibit characteristics of decreasing returns to scale (DRS), particularly in economically developed cities such as Shanghai, Nanjing, Suzhou, Wuxi, and Changzhou in Jiangsu Province. These areas suffer from over-expansion of higher education resources, which leads to a decline in resource utilization efficiency. The expansion of scale does not necessarily bring corresponding improvements in economic benefits; instead, it may lead to resource waste and inefficiency in educational output. Previous research has indicated that in some regions of China, higher education research activities are in a stage of decreasing returns to scale, with low research efficiency and significant disparities in research efficiency and resource utilization across regions (Rui Li, 2017). Therefore, enhancing resource allocation efficiency, improving educational quality, optimizing the layout of higher education resources, and promoting the coordination between higher education and regional economic development have become urgent issues that need to be addressed.

3. Regional Differences and the Balanced and Coordinated Development of Higher Education

The results of the DEA model and spatial analysis indicate that the distribution of higher education resources in the Yangtze River Delta region exhibits significant imbalance. Cities in northern Jiangsu, such as Suqian, Lianyungang, and Huaian, northern Anhui, such as Bozhou and Suzhou, and southwestern Zhejiang, such as Lishui, have low overall efficiency (θ) and scale efficiency (SE). For example, Suqian has an overall efficiency of 0.421, Bozhou has 0.294, and Lishui has 0.273, all of which are far below efficient levels. Coupled with these areas exhibiting increasing returns to scale (IRS), it suggests that higher education resources have not yet reached an optimal configuration and that there is room for optimization and moderate expansion. Research indicates that there are significant differences in higher education resources between regions, and a clear "Matthew Effect" exists between the higher education system and the economic system (Huanliang Wang, 2022).

Against this backdrop, there should be increased investment in higher education resources in underdeveloped areas to address the inefficiencies in resource supply and utilization. Additionally, attention should be given to aligning higher education training with local economic needs, promoting the rational distribution of higher education resources across regions, narrowing regional economic disparities, and achieving coordinated development in the Yangtze River Delta region. Research has shown that improving the efficiency of education funding and coordinating the relationship between the level of economic development and the scale of higher education is crucial for promoting the development of higher education in underdeveloped areas.

Conclusion and suggestions

This study demonstrates that in the Yangtze River Delta (YRD), the expansion of higher education enrollment does not automatically translate into higher per capita GDP, and that significant disparities exist in the efficiency of resource allocation across cities. While Zhoushan, Wuxi, and Xuancheng exhibit optimal efficiency in utilizing educational resources, major urban centers such as Shanghai and Hefei reveal inefficiencies, reflecting problems of over-expansion, diminishing returns to scale, and the misalignment between educational outputs and local industrial needs. Spatial econometric analysis further indicates that the relationship between higher education resources and economic development is heterogeneous and not uniformly positive, with weak global spatial correlation and localized clusters of imbalance. These findings confirm that the quality, efficiency, and relevance of higher education matter more than mere enrollment growth, and that differentiated regional strategies are necessary to optimize educational investments.

From a policy perspective, the results suggest that greater emphasis should be placed on enhancing the efficiency of resource utilization, particularly in underdeveloped areas where investments have not yet achieved optimal outcomes. Coordinated allocation mechanisms across provinces should be strengthened to mitigate regional disparities and support the integration of the YRD. At the same time, improving the match between university training and labor market needs is crucial. Strengthening university–industry linkages can improve graduate employability, stimulate innovation, and promote industrial upgrading. Such measures would not only increase the economic returns of higher education but also enhance the role of universities as drivers of social and technological progress.

This research also generates new knowledge with implications for society and communities. It challenges the conventional assumption that higher education expansion

inherently drives economic growth, showing instead that efficiency and alignment are the determining factors. The study highlights the importance of equitable access to high-quality education in reducing regional inequality and promoting balanced development. By clarifying the inefficiencies in current resource distribution, it provides evidence to guide reforms that can help local communities benefit more directly from educational investments. Aligning higher education outputs with industry needs will strengthen the competitiveness of the labor force, foster innovation capacity, and generate broader social benefits, from employment opportunities to community development and social mobility.

Future research should build upon these findings by adopting approaches that capture both temporal and qualitative dimensions. Dynamic panel data analysis could be used to reveal longer-term causal effects of higher education on economic outcomes. Beyond enrollment figures, micro-level and qualitative data such as graduate employment, innovation capacity, and the social relevance of higher education outputs would provide a more comprehensive picture of educational effectiveness. Further investigation into policy and governance structures is also essential to explain disparities in resource allocation and to propose structural reforms that align higher education with regional development strategies. Additionally, spatial research should be broadened to account for cross-regional linkages within the YRD, while innovative modeling could incorporate Shanghai's unique administrative position into spatial frameworks. Such extensions will not only refine the measurement of higher education efficiency but also deepen understanding of its broader societal and economic impacts.

New knowledge and the effects on society and communities

The data in this study comes from the 2022 year-end statistics in the statistical yearbooks of the three provinces and one city in the Yangtze River Delta, and is static in nature. The results derived from the DEA model only reflect the static characteristics of higher education resource allocation efficiency at a specific point in time, without revealing the dynamic development trend. In terms of spatial analysis, the study is based on province-level administrative units for overall spatial analysis, while discussions at the city level are conducted province by province. This approach is limited by the administrative structure of Shanghai – as a provincial-level unit, Shanghai cannot be analyzed in spatial relation with the other 40 cities in the Yangtze River Delta as a whole, thus limiting the exploration of its spatial spillover effects on surrounding cities. This is a limitation of the present study, and future research could explore the changing trends in higher education resource allocation efficiency from a dynamic perspective by incorporating data over a longer time series, while also strengthening the spatial impact analysis of Shanghai and its surrounding cities within regional integration to address the gaps in the current research.

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