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Article

Research on Optimal Allocation of Civic Education Resources in Civil Engineering Disciplines Based on Mathematical Planning Methods

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Abstract: In order to better cultivate talents in the new era, it is necessary to strengthen the resource allocation of higher education's Civic and Political Education, so that educators and educated people subconsciously strengthen the cognition of the importance of Civic and Political Education. In this paper, the DEA-BCC model is selected to statically analyze the resource allocation efficiency of higher Civic and Political Education through the static perspective, using the data envelopment analysis method. Combined with Malmquist index and Dagum index, it evaluates the temporal and spatial differences in the allocation efficiency of Civic and Political education resources from a dynamic perspective. Civic and political courses of higher civil engineering majors are selected as assessment objects to construct civil engineering civic and political education resources and evaluate the effectiveness of civic and political resource allocation for civil engineering major courses. Among the 31 provinces in China, the comprehensive efficiency scores of Tianjin, Inner Mongolia, Jilin, Heilongjiang, Zhejiang, Fujian, Hubei, Hainan, and Tibet are 0.914, 0.988, 0.903, 0.845, 0.984, 0.948, 0.936, 0.826, and 0.965, respectively, which are lower than 1, indicating that there is some degree of resource allocation degree of inefficiency in resource allocation. Taking 2012 as the base period, then the efficiency gap in China's higher education resource allocation will decrease by 3.671% per year in 2023, and the spatial gap in China's higher education investment efficiency is shrinking.

Keywords: DEA-BCC; Dagum index; Malmquist index; Civic education resource allocation; spatial and temporal differences

1. Introduction

With the rapid development of China's economy, the social demand for civil engineering talents is growing [1]. Generally speaking, civil engineering majors are more emphasized on research and practice, so in their classroom teaching, they tend to pay more attention to the teaching of professional theory and skills [2-3]. As a result, compared with students of liberal arts majors, civil engineering students are relatively weak in humanistic literacy [4]. However, merely mastering technology and professional knowledge can no longer meet the requirements for the comprehensive development of engineering talents [5]. As one of the core courses in college education, the Civics program plays an important role in shaping students' values, ways of thinking and sense of social responsibility [6-7]. It can also cultivate engineering and technical talents with global vision and innovative consciousness to better adapt to the complex and changing social environment [8-9]. In order to cultivate excellent civil engineering professionals who are technically competent and ideologically qualified, colleges and universities must, while imparting knowledge and skills, fully integrate the ideological and political elements contained in each course that can be tapped into, and maximize the nurturing ability of all kinds of courses in civil engineering majors [10-12]. At the same time, due to the lagging content of engineering course materials compared to the actual development of engineering, teachers should scientifically configure the teaching resources of the course of ideology and politics in the lectures, and increase the latest actual engineering cases of the specialty, so that the students can understand the latest development of the discipline in a timely manner [13-16].

This paper utilizes the data envelopment analysis method to comprehensively measure and analyze the input and output data of the resource allocation efficiency of Civic Education in Civil Engineering discipline. Total factor productivity analysis is utilized to reflect the data changes in the decision-making unit over the cycle through the Malmquist index. Using the Gini coefficient proposed by Dagum, the regional differences in economic phenomena are decomposed into three parts: intra-regional difference contribution, net contribution of inter-regional difference and hypervariable density contribution, further distinguishing the source and composition of regional differences in economic phenomena. The optimal allocation evaluation model system of civil engineering civic education resources is constructed, and the indicators in the evaluation model are used as decision-making units to evaluate the static and dynamic efficiency of the allocation efficiency of civil engineering civic education resources across the country, and to analyze the trend of the evolution of the spatial polarization of the distribution of civic education resources.

2. Optimal Allocation of Resources for Civic Education in Civil Engineering Disciplines Based on DEA

2.1. Model for Measuring Resource Allocation Efficiency of Civic Education in Civil Engineering Disciplines

The core principle of Data Envelopment Analysis (DEA) lies in the fact that through the comprehensive in-depth analysis of input and output data, it aims to obtain quantitative indicators of the comprehensive relative efficiency of each decision unit, so as to accurately assess whether each decision unit meets the effectiveness criteria of DEA [17]. In daily research, data envelopment analysis method adopts static perspective for decision unit evaluation mainly includes DEA-CCR model and DEA-BCC model, the principle of the two models is the same, but the difference is that the DEA-CCR model is an evaluation system to study multiple inputs and outputs of decision units under the assumption of constant scale reward, focusing on evaluating the scale validity of decision units and the technical effectiveness. The DEA-BCC model, on the other hand, is a kind of evaluation under the assumption of variable remuneration, focusing on evaluating the technical effectiveness of decision-making units. Therefore, in this paper, the DEA-BCC model is selected to analyze the static analysis of higher education resource allocation efficiency [18]. The formula of BCC model is as follows:

$$\begin{cases} \min[0-\varepsilon(e^T s^- + e^T s^*)] \\ s.t.\sum_{j=1}^{n} x_{ji}\lambda_j + s^- = \theta x_i, l = 1,2,\cdots,L \\ \sum_{j=1}^{n} y_{jn}\lambda_j - s^+ = y_m, m = 1,2,\cdots,M \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0, j = 1,2,\cdots,n \end{cases} \tag{1}$$

In the above equation, n denotes the number of decision units, representing the number of multiple decision units to be evaluated. θ denotes the efficiency value, also known as the efficiency coefficient, which measures the resource allocation efficiency of the decision unit. The larger the θ value, the more efficient the resource allocation of the decision unit, and vice versa. λ denotes the weighting variable, which measures the importance of each decision unit in the assessment process. $s-(s-\geq 0)$ and $s+(s+\geq 0)$ denote slack and residual variables, respectively, which are used to determine whether the decision unit has reached the optimal state. The ε denotes the Archimedean infinitesimal, which is used to set the judgment criteria.1 and 2 are denoted as input and output vectors, respectively, which contain various input and output indicators of the decision unit. Based on these concepts, the efficiency of the decision unit can be categorized into the following three cases:

If $\theta = 1$ and $s- = s+ = 0$, the DMUj is said to be DEA efficient at this point. This means that the decision unit is optimal in all aspects and the resource allocation is most efficient.

If $\theta = 1$ and $s- \neq s+ \neq 0$, then the DMUj is said to be weakly effective for DEA. This means that the decision unit has reached optimality in some aspects, but there is still room for improvement.

If $\theta < 1$, the DMUj has misallocation of resources and is said to be DEA ineffective. This means that the decision unit is deficient in resource allocation and needs to be optimized and adjusted.

2.2. Spatial and Temporal Differences in Resource Allocation Efficiency in Civic Education

2.2.1. Malmquist Index

Malmquist index reflects the change of decision-making unit in two cycles, visual evaluation of the efficiency of decision-making unit year changes, but also can analyze the production efficiency, technical efficiency and technological progress and other factors for the total factor productivity (Tfpch), and therefore also known as "total factor productivity" analysis. This index is expressed mathematically as [19]:

$$Tfpch = M_0(x^{t+1}, y^{t+1}; x^t, y^t) = TECHch \times EFFch = TECHch \times (Sech \times Pech) \quad (2)$$

where $Tfpch = M_0(x^{t+1}, y^{t+1}; x^t, y^t) = \sqrt{\frac{E^t(x^{t+1}, y^{t+1})}{E^t(x^t y^t)} \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^{t+1}(x^t, y^t)}}$, M_0 denote the M index of the decision cell from period t to $t+1$, i.e., total factor productivity Tfpch, x is the input vector, and y is the output vector.

TECHch represents the efficiency of technological progress, which measures the change in efficiency resulting from the creation of new technologies or the development of innovations, and is given by the following formula:

$$TECHch = \sqrt{\frac{E^t(x^t, y^t)}{E^{t+1}(x^t, y^t)} \frac{E^t(x^{t+1}, y^{t+1})}{E^{t+1}(x^{t+1}, y^{t+1})}} \quad (3)$$

EFFch represents technical efficiency, which is the product of pure technical efficiency (Pech), which represents changes in the level of the system or management, and scale efficiency (Sech), which represents changes in the efficiency of scale, with the following formula:

$$EFFch = Sech \times Pech = \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \quad (4)$$

2.2.2. Dagum Index

The Gini coefficient proposed by Dagum takes the distributional status of the subsample into account, overcoming the defect of cross-over of sample data, and can further decompose the regional differences in economic phenomena into three parts: the contribution of intra-regional differences (Gw), the net contribution of inter-regional differences (Gnb), and the contribution of hyper-variable density (GT), which can then distinguish the source and composition of the regional differences in economic phenomena, and has a significant advantage in the study of spatial unbalanced economic problems has a significant advantage in the study of spatial unbalanced economic problems. The calculation of Dagum's Gini coefficient is publicized as follows:

$$\mathrm{G} = \frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{nj}\sum_{r=1}^{nh} | y_{ji} - y_{hr} |}{2n^2 y} \quad (5)$$

$$\overline{Y_h} \leq \ldots \overline{Y_j} \leq \ldots \overline{Y_k} \quad (6)$$

G represents the Gini coefficient, n represents the number of schools in this study, k is the number of districts carved out, $\overline{y}$ represents the average value of the combined efficiency of the schools, y_{ji} and y_{hr} denote the value of the combined efficiency of a particular school within the j and h districts, and

nj and nh represent, respectively, the the number of schools within the j and h districts, respectively:

$$G_{jj} = \frac{\frac{1}{2Y_j}\Sigma_{i=1}^{nj}\sum_{r=1}^{nk}|y_{ji} - y_{hr}|}{n_j^2} \tag{7}$$

$$G_w = \sum_{j=1}^{k} G_{jj} \cdot p_j s_j \tag{8}$$

G_{ij} is the Gini coefficient within the j region, $j = 1, 2 \cdots\cdots, k$, G_w is the contribution to intra-regional variation, $p_j = nj / n$ represents the number of schools within the j region as a proportion of the total national number of colleges and universities, $s_j = nj \cdot \overline{y}_j / n \cdot \overline{y}$ represents the share of the efficiency value of all schools in the j region to that of all schools in the country:

$$G_{jh} = \frac{\sum_{i=1}^{nj}\sum_{r=1}^{nh}|y_{ji} - y_{hr}|}{n_j n_h(\overline{Y}_j + Y\overline{Y}_h)} \tag{9}$$

$$G_{nb} = \sum_{i=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j) D_{jh} \tag{10}$$

$$G_t = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j) 1 - (D_{jh}) \tag{11}$$

G_{jh} is the difference in tertiary education efficiency between the j region and the h region, G_{nb} is the contribution to inter-regional differences, G_t is the hypervariance density, and the relationship between the Gini coefficients is $G = G_w + G_{nb} + G_t$:

$$D_{jh} = (d_{jh} - p_{jh}) / (d_{jh} + p_{jh}) \tag{12}$$

$$d_{jh} = \int_0^\infty dF_j(y) \int_0^y (y - x) dF_h(x) \tag{13}$$

$$p_{jh} = \int_0^\infty dF_h(y) \int_0^y (y - x) dF_j(x) \tag{14}$$

D_{jh} is the relative impact of the level of school efficiency between region j and region h. d_{jh} represents the difference in school efficiency between region j and region h, i.e., the mathematical expectation of the summation of all the sample values of $y_{ji} - y_{hr} > 0$ within regions j and h. p_{jh} is the mathematical expectation of the sum of all $y_{hr} - y_{ji} > 0$ sample values within the j and h regions, and F_j and F_h denote the distribution functions of cumulative densities of the j and h regions, respectively.

2.2.3. DEA-Malmquist Exponential Modeling

The DEA-Malmquist index model is a combination of the DEA model and the Malmquist index for the dynamic measurement of resource allocation efficiency. Initially, the Malmquist index was proposed by Swedish economists and used to analyze the change of social consumption in different stages of production. With the deepening of research, in 1994, scholars combined the nonparametric method of linear programming with the Malmquist productivity index to comprehensively assess the growth of total factor productivity (TFP) and its dynamics, and reconstructed the TFP growth rate in the framework of the distance function, which was refined into two dimensions, namely, technological progress and efficiency change. First, technological progress refers to the ability to adopt new technologies, processes or resources in the production process, which is important for increasing productivity. By analyzing technological progress, it is possible to identify which industries or enterprises have an advantage in technological innovation, thus providing targeted guidance to policymakers. Second, efficiency changes include the allocative efficiency and scale efficiency of production factors. Configuration efficiency refers to the optimal combination of production factors in the production process, which maximizes output. Scale efficiency refers to the corresponding change in productivity of an enterprise when the scale of production changes. By analyzing changes in efficiency, it is possible to identify which industries or enterprises have problems with resource allocation and production scale, and thus provide policymakers with a basis for improvement.

As a quantitative index used to measure the change of total factor productivity, the Malmquist productivity index is constructed based on the efficiency value calculated by data envelopment analysis (DEA), i.e., the Malmquist productivity index is obtained by interpreting the distance function and constructing a combination of the corresponding distance functions. By comparing and analyzing the total factor productivity change from period t to period t+1, it can be judged that if the Malmquist index is greater than 1, it indicates that the total factor productivity in this period has achieved growth and is in an upward stage. If the Malmquist index is less than 1, it means that total factor productivity has declined during this period. If the Malmquist Index is equal to 1, it means that total factor productivity has remained stable during the period in question.The Malmquist Index can be subdivided into two parts: first, it reflects the technological progress (TC) demonstrated by the decision-making unit (DMU) in comparison with the production frontier. Second, it reveals the technical efficiency change (TEC) of the decision-making unit (DMU) in catching up with the production frontier. Further, technical efficiency change (TEC) can be subdivided into pure technical efficiency change (PTEC) and scale efficiency change (SEC). The Malmquist index and its decomposition expression based on period t, under the condition that the returns to scale remain constant, are shown below:

$$
\begin{aligned}
&M_c^t(x_t, y_t, x_{t+1}, y_{t+1}) \\
&= \left[\frac{D_c^t(x_{t+1}, y_{t+1})}{D_c^t(x_t, y_t)} \times \frac{D_c^{t+1}(x_{t+1}, y_{t+1})}{D_c^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}} \\
&= \frac{D_c^{t+1}(x_{t+1}, y_{t+1})}{D_c^t(x_t, y_t)} \times \left[\frac{D_c^t(x_{t+1}, y_{t+1})}{D_c^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_c^t(x_t, y_t)}{D_c^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}} \\
&= \frac{D_v^{t+1}(x_{t+1}, y_{t+1})}{D_v^t(x_t, y_t)} \times \left[\frac{D_c^{t+1}(x_{t+1}, y_{t+1})}{D_c^t(x_t, y_t)} \times \frac{D_v^t(x_t, y_t)}{D_v^{t+1}(x_{t+1}, y_{t+1})}\right] \times \left[\frac{D_c^t(x_{t+1}, y_{t+1})}{D_c^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_c^t(x_t, y_t)}{D_c^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}}
\end{aligned} \tag{15}
$$

2.3. Evaluation Model Construction of Optimal Allocation of Civil Engineering Civic Education Resources

2.3.1. The Construction of the Evaluation Model of the Allocation of Resources for Civics in DEA Courses

Table 1 shows the evaluation system of civil engineering civic education resource allocation indicators. The Civics courses of higher civil engineering majors are selected as the assessment object to evaluate the effect of Civics resource allocation in civil engineering majors' courses. The effect evaluation is mainly based on two aspects: input and output. The construction of the indicator system for the input of teaching resources and the output of teaching for the construction of Civic Politics of civil engineering professional courses adopts the Delphi method8 and invites the first-line teachers, teaching administrators, and experts in Civic Politics of higher civil engineering colleges and universities to screen and confirm the indicators. After two rounds of questionnaire surveys, six primary indicators and 17 secondary indicators were finally identified. Meanwhile, the expert reliability study shows that the two rounds of experts are highly concerned about constructing the evaluation index system of civil engineering professional course civic resources allocation, and the experts have a high degree of authority.

(1) Indicators and Measurement of Civics Teaching Resource Input. The first-level indexes of

teaching resources input are manpower input and financial input. Combined with the actual situation, the human resource input is measured by the preparation time invested by teachers in each class hour, and the financial resource is measured by the funding input of course Civics teaching reform.

(2) Table 2 shows the measurement of indicators for evaluating the effectiveness of course Civics construction. Civics Teaching Resources Effectiveness Output Indicators and Measurement. The output of teaching results includes 4 level 1 indicators of knowledge effect, teaching satisfaction, teaching ability and behavioral effect. The second-level indicators are screened from the teaching quality evaluation and special questionnaires formed by the school in the past to make a comprehensive evaluation of the relevant indicators. Specific measurements are as follows: knowledge effect is measured through students' performance, teaching satisfaction is measured through students' questionnaires, behavioral effect is statistically measured through counselors' questionnaires on students' behavioral performance, and teaching ability is measured with teachers' peers.

Table 1. The evaluation system of the resource allocation index for civil engineering.

Project electricity	First-level indicator	Secondary indicators
1 Teaching resources (Input)	Human resource input	Teacher preparation time
	Financial input point	Thinking of political reform
Teaching achievements (outputs)	Knowledge effect	Normal grade
		Test results
	Teaching satisfaction	Teaching attitude
		Lecture preparation
		Teaching skill
		Academic communication
		Course resources
		Comprehensive evaluation
	Teaching ability	Teaching design
		Teaching group
		Teaching characteristics
	Behavioral effect	Actively understand the thinking in the course
		To solve the problem of life and study by thinking about the content of government
		Professional areas combine thinking politics to innovate
		Interested in civil engineering courses

Table 2. The evaluation measure of the efficiency evaluation of the curriculum.

Project	Indicator	Measuring method
Teaching resources (Input)	Human resources	The teacher spends the time in each hour(X1)
	Financial resources	The curriculum is refunded by the total amount of money(X2)
Teaching achievements (outputs)	Knowledge effect	Student score(Y1)
	Teaching satisfaction	Students score scores on teaching satisfaction(Y2)
	Teaching ability	The provost and the teacher's peer review(Y3)
	Behavioral effect	The counselor's assessment of the student's behavior(Y4)

2.3.2. Data Envelopment Analysis Model and Analysis Process

The key to the use of data envelopment analysis is to determine the model, and the classical ones are CCR model and BCC model. Assume that there are n DMUs, each with m inputs, denoted as $x_i = (i = 1, 2...., m)$, and the input weights are denoted as $v_i = (i = 1, 2...., m)$. There are q kinds of outputs, denoted as $y = (r = 1, 2, \cdots q)$ with input weights denoted as $u_i = (i = 1, 2...., q)$, whose linear programming model is transformed and dyadically treated by equivalence transformation. With s^- as the introduced slack variable, s^+ as the introduced residual variable, and θ representing the efficiency value of the decision unit. The optimal solution of the model is denoted by θ^*, and the range of θ^* is (0, 1], $\theta^* = 1$, which indicates that the evaluation unit DMU_k is in a technically efficient state, and at this time $s^+ = 0, s^- = 0$. When $\theta^* < 1$ then the evaluation unit DMU_k is in a technically invalid state:

$$\begin{cases} \min \theta \\ s.t.\sum_{i=1}^{n} \lambda_j x_{ij} + s^+ = \theta x_{ik} \\ \sum_{i=1}^{n} \lambda_j y_{ij} - s^- = \theta y_{ik} \\ \lambda \geq 0, j = 1,2,...,n \\ s^+ \geq 0, s^- \geq 0 \end{cases} \quad (16)$$

3. Evaluation of the Efficiency of Resource Allocation for Civil Engineering Civic Education Nationwide

3.1. National Level: Evaluation of the Efficiency of Resource Allocation in Chinese Higher Education

3.1.1. Analysis of Static Efficiency Evaluation Results

The study considers the inputs and outputs of civic education resources in 31 regions of China between 2019 and 2023 as 31 Given the variability in the size of higher education institutions, the study is based on the CCR model and at the same time introduces the BCC model for a comprehensive number of decision-making units ($DMU_j, j = 1,2,...,31$), aiming at assessing the efficiency of these provinces in terms of the allocation of civic education resources. Analyzing. Meanwhile, considering that the goal of higher education is usually to maximize output under the constraints of available resources, this study adopts an output-oriented model for efficiency assessment. By using the DEA-BCC model, this paper empirically analyzes the efficiency of Civics education resource allocation in 31 provinces during the period from 2019 to 2023.Table 3 shows the results of the evaluation of Civics education resource allocation efficiency.

(1) Analysis of comprehensive technical efficiency results

The provinces that performed well in the comprehensive technical efficiency evaluation of China's higher education resource allocation include Beijing, Hebei, Shanxi, Liaoning, Shanghai, Jiangsu, Anhui, Jiangxi, Shandong, Henan, Hunan, Guangdong, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. These provinces have an overall efficiency score of 1, indicating that the maximum possible output is achieved in utilizing current educational resources (e.g., faculty, financial support, and facilities). This means that HEIs in these provinces are doing a better job of allocating and utilizing resources without significant waste, significantly supporting the development of new quality productivity. In contrast, the comprehensive efficiency scores of Tianjin, Inner Mongolia, Jilin, Heilongjiang, Zhejiang, Fujian, Hubei, Hainan, and Tibet are 0.914, 0.988, 0.903, 0.845, 0.984, 0.948, 0.936, 0.826, and 0.965, respectively, and the overall efficiency scores of these provinces are lower than 1. This suggests that HEIs in these provinces are allocating their resources There is a certain degree of inefficiency, especially in Heilongjiang and Hainan, indicating that there is a large room for improvement, which can be achieved by strengthening industry-university-research cooperation, technological transformation, scientific research investment and international exchanges, so as to enhance the efficiency of higher education resource allocation and to promote the development of new-quality productivity.

(2) Analysis of pure technical efficiency results

Pure technical efficiency measures the efficiency performance under the exclusion of the influence of scale effect. Provinces that reach the standard of pure technical efficiency include not only all the provinces with a score of 1, but also some provinces that do not have a full score of comprehensive efficiency, such as Jilin, Heilongjiang, Hainan and Tibet, which also perform better in pure technical efficiency. This suggests that universities in these provinces are maximizing efficiency in technology and process management, and that the problem may lie in scale efficiency. Provinces with problems in technical efficiency include Tianjin, Fujian and Hubei, and the pure technical efficiency of these provinces is 0.965, 0.996 and 0.954, respectively. The pure technical efficiency of these provinces is slightly lower than 1, although the difference is not big, but this shows that there is still room for further improvement in management and technology utilization in these provinces.

(3) Analysis of scale efficiency results

Scale efficiency reflects the impact of university size on efficiency, including increasing returns to scale (irs) and decreasing returns to scale (drs). According to the results of efficiency evaluation, the scale efficiency score of the vast majority of provinces is 1, which means that the scale of colleges and universities in these provinces is set appropriately, with neither too large a scale leading to a waste of resources nor too small a scale leading to a failure to give full play to the scale effect. Among them, the provinces with increasing returns to scale include Tianjin, Jilin, Heilongjiang, Zhejiang, Fujian, Hainan, and Tibet with scale efficiency scores of 0.985, 0.926, 0.851, 0.996, 0.984, 0.831, and 0.948, respectively, which show increasing returns to scale, indicating that colleges and universities in these provinces can increase their efficiency by increasing their scales, and in particular, the scales of Heilongjiang and Hainan have relatively low scale efficiencies, indicating that increasing resource inputs may lead to greater efficiency gains. Hubei Province, with a scale efficiency of 0.985, is the only province showing diminishing returns to scale, which indicates that the scale of colleges and universities in Hubei Province may be too large, and further expansion of the scale will reduce efficiency, and it is necessary to consider optimizing the existing resource allocation or adjusting the scale structure.

Table 3. The evaluation results of the resource allocation efficiency of the education resource.

Province coding	Province name	Integrated efficiency	Pure technical efficiency	Scale efficiency	Scale compensation
1	Beijing	1	1	1	-
2	Tianjin	0.914	0.965	0.985	irs
3	Hebei	1	1	1	-
4	Shanxi	1	1	1	-
5	Inner Mongolia	0.988	0.974	1	-
6	Liaoning	1	1	1	-
7	Jilin	0.903	1	0.926	irs
8	Heilongjiang	0.845	1	0.851	irs
9	Shanghai	1	1	1	-
10	Jiangsu	1	1	1	-
11	Zhejiang	0.984	0.948	0.996	irs
12	Anhui	1	1	1	-
13	Fujian	0.948	0.996	0.984	irs
14	Jiangxi	1	1	1	-
15	Shandong	1	1	1	-
16	Henan	1	1	1	-
17	Hubei	0.936	0.954	0.985	drs
18	Hunan	1	1	1	-
19	Guangdong	1	1	1	-
20	Guangxi	1	1	1	-
21	Hainan	0.826	1	0.831	irs
22	Chongqing	1	1	1	-
23	Sichuan	1	1	1	-
24	Guizhou	1	1	1	-
25	Yunnan	1	1	1	-
26	Tibet	0.965	1	0.948	irs
27	Shaanxi	1	1	1	-
28	Gansu	1	1	1	-
29	Qinghai	1	1	1	-
30	Ningxia	1	1	1	-
31	Xinjiang	1	1	1	-

Note: irs, drs and - respectively represent increasing returns to scale, decreasing returns to scale and unchanged returns to scale.

3.1.2. Non-DEA Effective Unit Projection Analysis

DEA is a measure of relative efficiency that determines the efficiency of decision units by comparing their inputs and outputs under identical conditions. In DEA modeling, decision units with an efficiency score of 1 are considered efficient, while those with a score below 1 are considered non-DEA efficient. The purpose of the projection analysis of non-DEA efficient units is to determine how non-efficient decision-making units need to adjust their inputs or outputs in order to reach the efficiency frontier, and the method can help universities to identify deficiencies in the utilization of their resources so that they can improve their educational quality and research output. Table 4 shows the input redundancy and output underutilization of higher education resource allocation in non-DEA efficient provinces. The following results are obtained by analyzing the output-oriented BCC model in DEAP2.1 software:

(1) Overall analysis

The non-DEA effective provinces indicate that these provinces have failed to achieve best practices in terms of existing resource allocation and management efficiency. They need to reduce inputs while maintaining the current level of outputs or increase outputs while maintaining the current level of inputs in order to realize efficiency gains. The results of the projection analysis reveal significant redundancies or deficiencies in some specific input or output indicators in these provinces, which are potential points for improvement. The human and financial indicators of input redundancy under Decision Units 2 and 13 are both zero.

(2) Input perspective analysis

From an input perspective, input redundancy means that the minimum amount required to achieve the current level of output is exceeded in the use of a given resource. For example, in decision unit 31, the redundancy of inputs for the manpower indicator is 109.493 and the input redundancy for the financial indicator is 0.

(3) Analysis from the output perspective

From the output perspective, output deficiency refers to the failure to reach its potential maximum value in a particular output indicator. Fujian and Hubei also show deficiencies in certain output indicators, suggesting that these provinces need to further explore ways to improve the efficiency and quality of their outputs. The output deficiencies under Decision Unit 22 are 800.548, 3.196, 40.408, and 2945.184 for Knowledge Effectiveness, Teaching Satisfaction, Teaching Competence, and Behavior Effectiveness, respectively.

Table 4. Non-DEA effective provincial resource allocation is redundant and underoutput.

Decision unit	Input redundancy(s-)		/	
	X1	X2		
2	0	0		
5	978.487	1957.364		
11	290.486	3948.645		
13	0	0		
17	3780.869	0		
22	517.049	4685		
31	109.493	0		
Decision unit	Underoutput (s+)			
	Y1	Y2	Y3	Y4
2	0	0	3434.485	0
5	0	0	426.198	54.284
11	58430.896	0	5049.648	0
13	0	1519.936	0	0
17	0	0	0	2846.395
22	800.548	3.196	40.408	2945.184

3.1.3. Analysis of the Results of the Dynamic Efficiency Evaluation

Table 5 shows the efficiency of the allocation of resources for civic education and the mean value of the Malmquist index and its index decomposition. From a national perspective, the efficiency of the allocation of resources for civic education in China as a whole shows a positive development. In particular, Shanghai, with an MI of 1.688, Heilongjiang Province, with an MI of 1.452, and Beijing, with an MI of 1.678, exhibit high Malmquist indices (MI), which implies that these provinces have realized significant technological advances or efficiency improvements during the assessment period. For example, Shanghai's efficiency mean of 1.000 as well as the highest MI indicates that it is not only extremely efficient in the allocation of resources for higher civic education, but also has made rapid technological progress, which may be related to its strong economic base and the importance it attaches to education. In contrast, the efficiency mean of 0.815 in Hainan Province and 0.869 in Ningxia Hui Autonomous Region, which have lower efficiency means, and especially the MI value of only 1.298 in Hainan Province, indicate relatively slower technological change in the province, which may reveal the challenges faced by these regions in terms of resource allocation and technological updating in education. Efficiency change (EC) and technological change (TC) are at or near 1.000 in most provinces, indicating that efficiency and technology have remained relatively stable in these provinces over the assessment period.

Table 5. Resource allocation and the Malmquist index mean.

Province	Region	Efficiency mean	MI	EC	TC
Beijing	East	0.975	**1.678**	1	1.678
Tianjin	East	0.956	1.385	1.036	1.388
Hebei	East	0.958	1.048	0.948	1.058
Shanxi	Middle	0.963	0.855	0.985	0.848
Inner Mongolia	West	0.864	0.985	0.906	1.068
Liaoning	Northeast	0.905	1.128	0.886	1.264
Jilin	Northeast	0.914	1.298	0.948	1.385
Heilongjiang	Northeast	0.866	**1.452**	0.908	1.085
Shanghai	East	1	**1.688**	0.866	1.264
Jiangsu	East	1	1.248	0.936	1.348
Zhejiang	East	0.942	1.469	1.038	1.485
Anhui	Middle	1	1.648	1	1.648
Fujian	East	1	1.168	1	1.158
Jiangxi	Middle	1	1.035	0.948	1.289
Shandong	East	0.953	1.064	1	1.164
Henan	Middle	1	1.098	1	1.064
Hubei	Middle	1	0.998	1.034	1.345
Hunan	Middle	1	0.748	1	1.298
Guangdong	East	1	1.064	0.997	1.248
Guangxi	West	0.926	1.458	1	1.048
Hainan	East	**0.815**	1.298	0.958	1.098
Chongqing	West	1	1.028	1	1.156
Sichuan	West	1	1.064	1	1.345
Guizhou	West	1	1.158	1	1.064
Yunnan	West	1	1.345	1	1.054
Tibet	West	0.968	1.064	0.798	1.348
Shaanxi	West	1	1.088	1	1.248
Gansu	West	1	1.185	1	1.158
Qinghai	West	0.908	0.978	1	0.948
Ningxia	West	**0.869**	0.956	0.898	1.164
Xinjiang	West	1	1.098	1	1.088

Note: In the table, MI represents the change in total factor productivity, EC represents the change in technical efficiency, and TC represents the change in technological progress.

Figure 1 shows the total factor productivity and decomposition of higher education resource allocation by subregion. These variations are not only reflected in the components of the Malmquist Index, but also in the unique challenges and limitations faced by different regions.

The efficiency index MI at the national level is 0.958, showing an overall improvement in the efficiency of higher education resource allocation. The technical change TC of 0.955 and the efficiency change EC of 1.002 both indicate that policy changes, economic growth, scientific and technological innovation, and societal development needs at the national level are driving improvements in the efficiency of educational resource allocation.

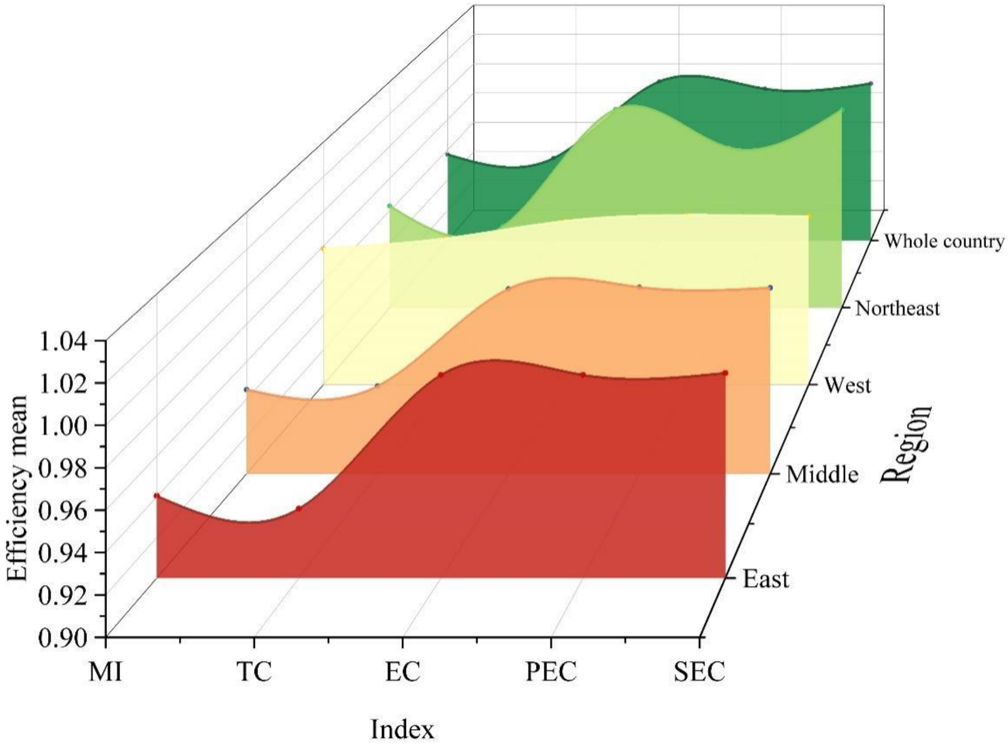

Figure 1. The total factor productivity of the education resource configuration.

3.2. Analysis of Spatial and Temporal Differences in Resource Allocation Efficiency of Civil Engineering Civic Education

3.2.1. Differences in the Efficiency of Investment in Civic Education Resources and Its Decomposition

Due to the vast territory, the development of China's regions is very unbalanced, which is also manifested in higher education, and there are some gaps in the efficiency of investment in higher education among China's regions. In this paper, China is divided into three regions: east, center and west. Then, according to the Dagum Gini coefficient method, China's higher education resource allocation efficiency is decomposed according to the three regions of east, center and west, and the spatial gap and subgroup decomposition gap of higher education resource allocation efficiency are measured respectively from 2012 to 2023, and Fig. 2 shows the higher education resource allocation efficiency and decomposition results. The Gini coefficient of resource allocation of national higher education civic education falls from 0.168 in 2012 to 0.094 in 2023.

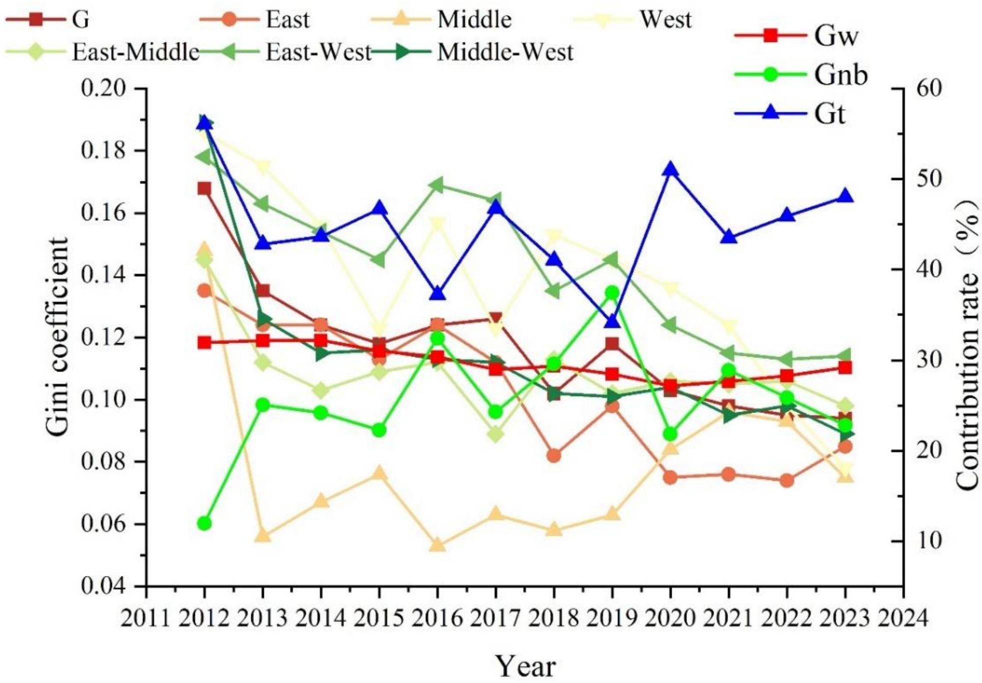

Figure 2. Efficiency and decomposition of higher education resource allocation.

3.2.2. Spatial Gap and Evolution of Investment Efficiency in Civic Education

From the trend of evolution, the spatial gap in the efficiency of China's higher education investment generally shows a downward trend during 2012-2023, and Figure 3 shows the trend of the spatial gap in the efficiency of China's higher education resource allocation from 2012 to 2023.

From 2012 to 2023, although the change in the spatial gap in China's higher education resource allocation efficiency is not smooth and has experienced several small fluctuations in individual years, such as a slight increase in 2016, 2017 and 2019, the general trend of change is downward. Assuming 2012 as the base period, China's higher education resource allocation efficiency gap declines by 3.671% per year in 2023. This indicates that the spatial gap in the efficiency of China's higher education investment has been decreasing over time.

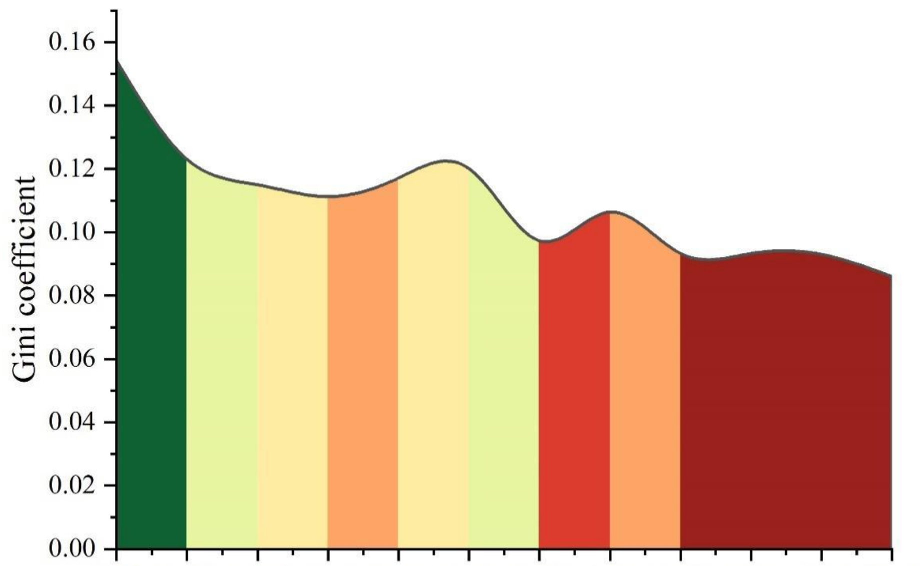

Figure 3. The spatial gap between China's higher education resources allocation efficiency.

3.2.3. Regional Disparities in the Efficiency of Resource Allocation for Higher Civic Education

(1) Intra-regional disparities and evolution

Figure 4 shows the intra-regional disparities and evolution from 2012 to 2023. From the trend of evolution, the intra-regional disparities in the three major regions of the East, Central and West are generally on a downward trend, but the magnitude of the decline is different. Again using 2012 as the base period, the average annual decline in intra-regional disparities in 2023 is 3.086%, 4.11% and 4.839% for the eastern, central and western regions, respectively. In terms of specific values, the gap within the western region is the largest during the 2012-2020 period, and since 2021, the gap within the eastern, central, and western regions has not differed much. In terms of regional division, the three major intra-regional gaps all show different degrees of repeated fluctuations, the eastern intra-regional gap is decreasing in most years, with only a very small increase in 2019 and 2021-2023, and the overall trend is decreasing, the central intra-regional gap has a larger fluctuation, showing repeated fluctuations of growth-decrease in the study period, but the overall trend is also decreasing and the overall trend of the gap within the Western region is also decreasing, maintaining a decreasing trend from 2012-2015 and then continuing to maintain a decreasing trend after a slight increase in 2016 (except for 2022).

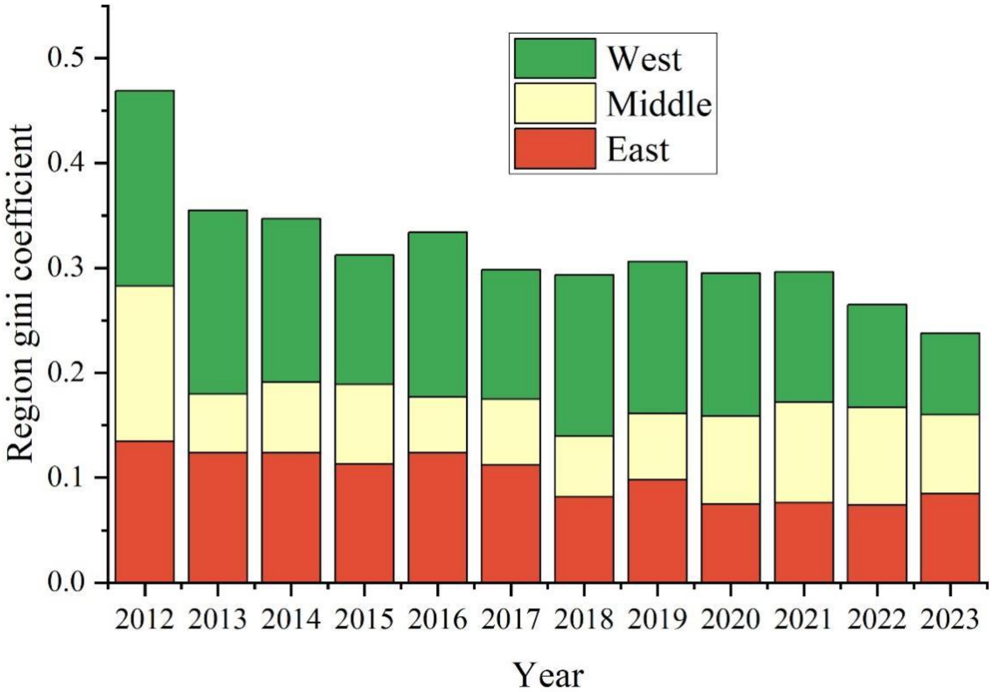

Figure 4. The gap and evolution of the region in 2012-2023.

(2) Inter-regional gap and evolution

Figure 5 shows the trend of the inter-regional gap from 2012 to 2023. From the evolution trend, the overall decrease in the inter-regional gap of China's higher education investment efficiency is greater than the increase in the time period of the study, and its inter-regional gap is on a decreasing trend. Considering 2012 as the base period, the annual average decline of the inter-regional gaps in East-Central, East-West and Center-West is 2.701%, 2.996% and 4.409% respectively, which can be seen that the gap in the Center-West is narrowing the fastest. In terms of specific values, in 2012, the inter-regional gap between center-west was the largest, in 2013-2019, the inter-regional gap between east-west was the largest, the inter-regional gap between center-west has been larger than the inter-regional gap between east-center, and in 2020-2023, the trend of the largest inter-regional gap between east-west will still be maintained, but the inter-regional gap between east-center exceeds the inter-regional gap between center-west. In terms of regional division, the changes in the East-Central and East-West inter-regional gaps have fluctuated repeatedly with a large magnitude, while the Central-West gap has only shown a small increase in 2016 and 2017, and declined in the remaining years, and its changes have been relatively smooth.

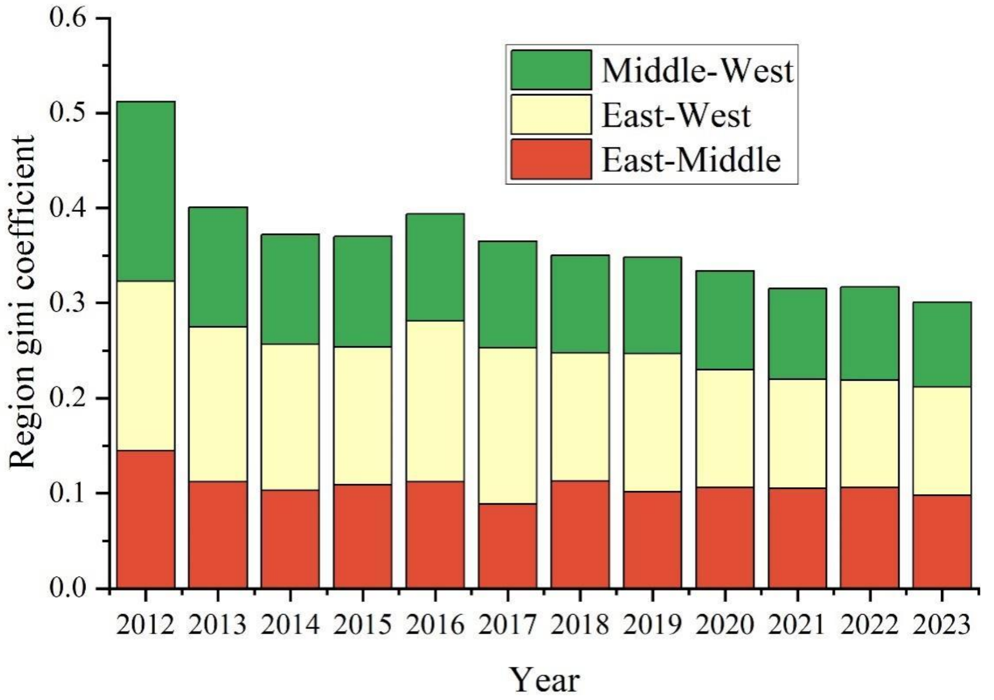

Figure 5. The trend of the gap between the 2012-2023 regions.

(3) Sources of spatial gap and contribution rate

From the perspective of the change trend, the distribution of the sources of spatial disparity is as follows: hypervariable density has always been the main cause of the spatial disparity in higher education investment efficiency in the periods of 2012-2018 and 2020-2023, while the size of the influence of the inter-region gap and the intra-region gap has been constantly and repeatedly fluctuating. In 2019, the inter-regional gap becomes the main factor leading to the spatial gap in higher education investment efficiency, while hypervariable density becomes a secondary factor. In terms of specific values, the change in the contribution rate of intra-regional disparity is relatively smooth, while the contribution rate of inter-regional disparity and hypervariable density fluctuates with a larger magnitude, and Figure 6 shows the change in the contribution rate of intra-regional disparity, inter-regional and hypervariable density. Assuming 2012 as the base period, the contribution rate of inter-regional disparity increases by 7.544% per annum, while the contribution rates of intra-regional disparity and hypervariable density decrease by 0.719% and 1.2% per annum, respectively. In addition, the contribution rate of intra-regional disparity repeatedly shows the changing trend of increasing and decreasing, but the fluctuation is not big, and its contribution rate always stays within the interval of (27,33), while the contribution rate of inter-regional disparity and hyper-variable density, although it also repeatedly increases and decreases, has a larger fluctuation, and the changing trend of the two is basically the opposite, and the contribution rate of hyper-variable density reaches the minimum of the examination period in 2019, which is 34.107 percent while the contribution rate of inter-regional disparity reaches the maximum value of 37.425% in 2019 within the examination period.

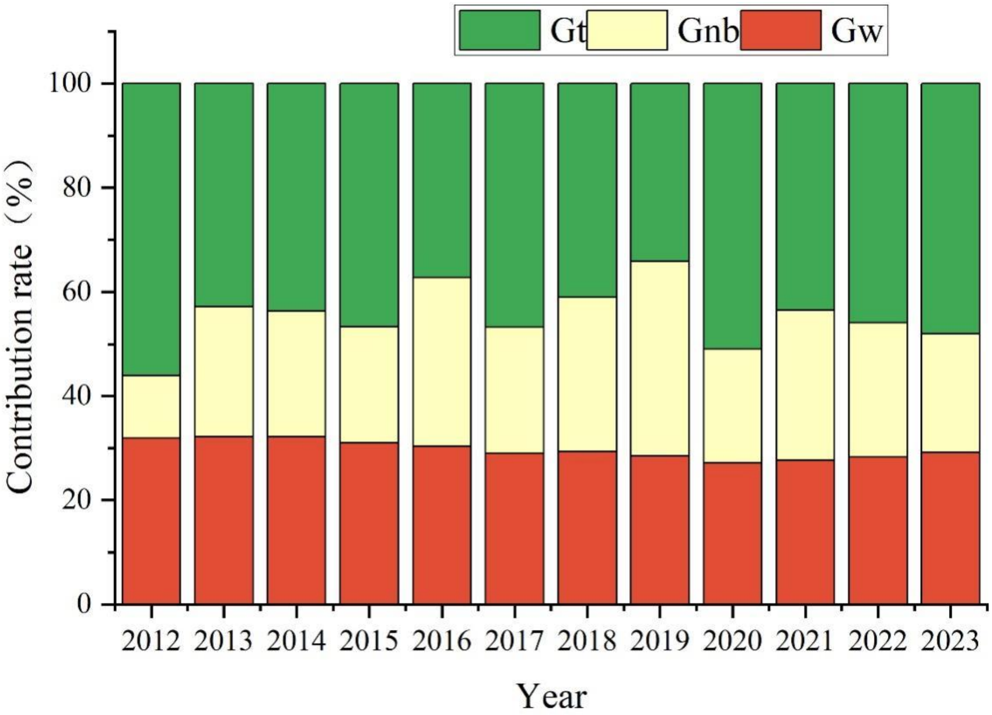

Figure 6. Changes in the differences in the region, regional and hypervariable density.

3.3. Trends in the Evolution of Spatial Polarization in the Distribution of Educational Resources

In the following, the dynamic evolution of the distribution of higher education resources is further analyzed by using the Kernel density estimation method in non-parametric estimation. Taking the student enrollment and student-teacher ratio as examples, the Gaussian Kernel function is used to make the Kernel density estimation of the distribution of higher education resources in China.

Figure 7 shows the Kernel density estimation of the student enrollment, and Figure 8 shows the Kernel density estimation of the teacher-student ratio. Whether it is the student enrollment or the teacher-student ratio, the centers of the density functions show obvious gradual movement to the right, which suggests that the level of China's tertiary education resources, as characterized by the student enrollment and teacher-student ratios, has been gradually increasing during the sample period of investigation. Comparing the distribution patterns of the four periods (2012, 2016, 2020 and 2023) in the figure, both the student-enrollment and student-teacher ratios show a bimodal distribution, which indicates that the distribution of student-enrollment and student-teacher ratios show a certain polarization trend.

In addition, comparing the gap between the peaks in the two graphs reveals a more pronounced bimodal distribution of school students, e.g., in 2023, the kernel density bimodal peaks of the logarithm of the number of school students are at 10.5 and 13.5, with kernel densities of 0.648 and 0.515, respectively. The bimodal distribution of the student-teacher ratio is relatively weak, which also indicates that the spatial polarization of the distribution of school students is stronger than that of the student-teacher ratio, which is consistent with the results of the spatial polarization index measure mentioned earlier.

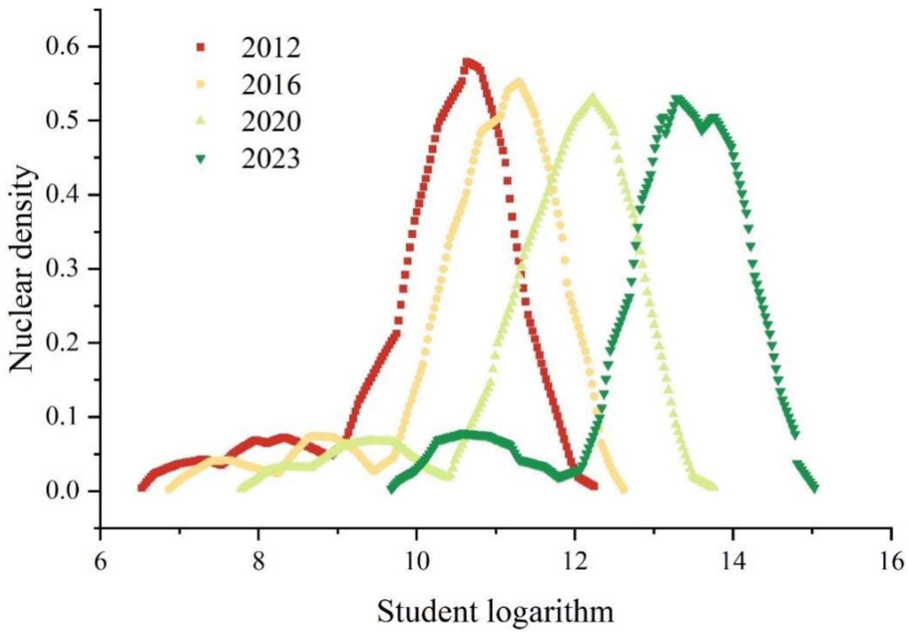

Figure 7. The kernel density estimation of the students in school.

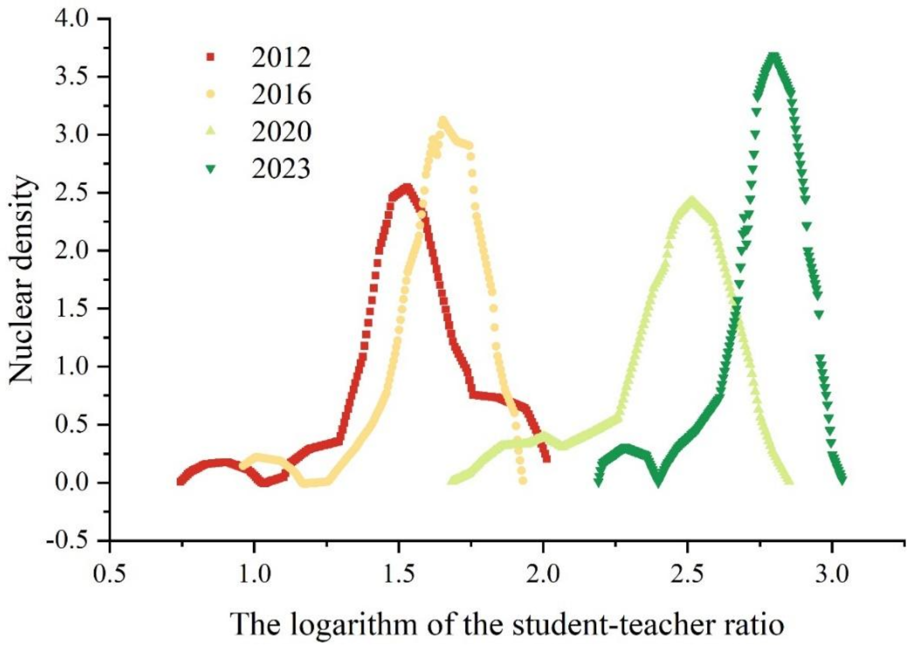

Figure 8. The kernel density estimation of the student ratio.

4. Conclusion

In this paper, the DEA-BCC model is selected for static evaluation of higher education resource allocation efficiency, and at the same time, the temporal and spatial differences of Civic Education resource allocation efficiency are reflected by Malmquist index, which is used to evaluate its dynamic efficiency. The civil engineering civic education resource allocation evaluation model is constructed to jointly assess the efficiency of civil engineering civic education resource allocation in terms of static, dynamic and spatio-temporal differences.

Tianjin, Jilin, Heilongjiang, Zhejiang, Fujian, Hainan, and Tibet show increasing returns to scale, with scale efficiency scores of 0.985, 0.926, 0.851, 0.996, 0.984, 0.831, and 0.948, respectively. Hubei province is the only province showing decreasing returns to scale, with a scale efficiency of 0.985.

The Malmquist index values of Shanghai, Heilongjiang, and Beijing are 1.688, 1.452, and 1.678, respectively, implying that these provinces have realized significant technological progress or efficiency enhancement during the assessment period, and that the allocation efficiency of resources for Civic Education is better.

Taking the Gaussian Kernel function to make the Kernel density estimation of the distribution of national higher education resources, the Kernel density bimodal peaks of the logarithm of enrolled students in 2023 are at 10.5 and 13.5, and the Kernel densities are 0.648 and 0.515, respectively, and the bimodal peaks of the enrolled students' distribution are more pronounced, which means that the spatial polarization of the distribution of the enrolled students is stronger than that of the faculty-to-student ratio.

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(1) Key Project of Teaching Reform Research by Hunan Provincial Department of Education: Reconstruction and Practice Research of Practical Teaching System for Civil Engineering Major Based on Outcome oriented Education (OBE) Concept under the Background of Engineering Education Certification (NO: HNJG2021-0125).

(2) Key Project of Teaching Reform Research by Hunan Provincial Department of Education: Research on the Renovation and Upgrading of Civil Engineering Majors to Serve the Beautiful Blueprint of "Three Highs and Four News" (202401000995). (3) Key Project of Teaching Reform Research by Hunan Provincial Department of Education: Construction and Practice of "Design Research" System for Architecture Majors in Local Universities Based on OBE-PBL - Taking the Course of "Fundamentals of Architectural Design" as an Example (202401001005).

(4) Ministry of Education Industry University Cooperation Collaborative Education Project: Building a Hu Collaborative BIMXR Virtual Simulation Practice Teaching Base Based on EIP-CDIO Talent Engineering and Innovation Capability Enhancement in Civil Engineering. (5) Hunan University of Technology Course Ideological and Political Demonstration Course "Fundamentals of Architectural Design". (6)Degree & Postgraduate Education Reform Project of Hunan Province (2023JGZD064). (7)Research Project on Teaching Reform in Ordinary Universities in Hunan Province (HNJG-20230746).

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