

The Spatio-Temporal Evolution of Public Resource Allocation in the Yangtze River Economic Belt from the Perspective of Fairness and Efficiency

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Abstract: The improvement in efficiency and fairness of public resource allocation is a key measure to promote social equality and justice. Based on the panel data of 110 cities in the Yangtze River Economic Belt from 2007 to 2017, this study measures and analyzes the Spatio-temporal evolution, regional gap, allocation efficiency, etc. of the public resource allocation in the YREB using spatial visualization, Dagum's Gini decomposition, and super-efficiency slacks-based measure (SBM) model. The following results were obtained: a) the overall public resource possession in the YREB showed a fluctuating upward trend, with an increase in average index close to 44%, from 0.3102 to 0.4467. b) the Dagum's Gini coefficient of public resource allocation presented an inverted "V"-shaped evolution trend, and the overall regional gap is mainly attributed to inter-regional discrepancies, of which the differences between the east and the central and between the central and the west contribute the most; c) the overall allocation of public resources in the region displayed a propensity for high-efficiency development, with the average overall configuration efficiency rising from 0.2688 to 0.7824. d) results of the coupling analysis of fairness and efficiency demonstrated a preoccupation for Jiangsu, Anhui, Sichuan, Guizhou, and Chongqing province to increase the input of public resources and for Zhejiang and Shanghai to enhance the social and economic output corresponding to public resources to further upgrade the efficiency of allocation; moreover, the fairness-efficiency coupling of Hunan, Hubei, Jiangxi, and Yunnan was extremely poor, which confirmed a structural deviation between the public resource input in the region and the local economic development.

1. Introduction

Since the Reform and Opening-Up policy, China's social public resources and services have witnessed rapid development. However, there are still different degrees of variations in the allocation of basic public services and resources in various provinces and cities, which has resulted in obvious regional differences and hindered social equality, justice, and the coordination of regional development. Correctly understanding and grasping the differences in the equalization of basic public services in various provinces [1] and the optimization of the efficiency and fairness of public resource allocation [2] are key measures to secure the improvement of people's livelihood and the promotion of social equality and justice.

In 2017, according to the "Opinions on Promoting the Disclosure of Government Information in the Field of Public Resource Allocation" issued by the State Council, the allocation of public resources refers to the distribution of public resources that has the following characteristics: should receive a high degree of social attention, should be public and publically beneficial, and should have a direct, extensive, and important impact on socio-economic development and the improvement of people's livelihood [3]. Therefore, the definition of public resource can be seen as a public service or product provided by the government and related public organizations with non-competitive consumption, non-exclusive benefit, and inseparable utility, playing a crucial role in improving people's livelihood and social development [4 -5].

The current academic research on the allocation of public resources mainly focuses on the

following levels. The first is the exploration of the contributory factors and the mechanism of the allocation of public resources. Studies have shown that there is a two-way interaction between the allocation of public resources and factors, including population migration, fiscal expenditure, and land supply, which have profoundly affected the fluctuating development of China's service industry, circulation industry, urbanization, and even the country's macroeconomy [5-10]. The second lies in the investigation of the allocation of a specific public resource from different perspectives, such as the analysis of the allocation of transportation infrastructure resources from the perspective of the relationship between the central and local governments and the perspective of new economic geography [11-12]. Another example is the empirical research upon the measurement of basic education resources, public medical resources, financial health expenditures, and labor income using entropy method, geographic detector model, Kernel density estimation [13-16]. The third centers on the evaluation of the theoretical mechanism and pattern of public resource allocation in different regions. In terms of theoretical mechanism, Hong assessed the influence of market and government on the allocation of public resources [17-18], and Wu et al. discussed the improvement measures and reasons for the formation of the differential pattern of public resource allocation between urban and rural areas, and in intra-urban areas [19-20]. In terms of empirical research, some scholars have analyzed the spatial pattern and promotion path of public services in different areas such as counties, urban agglomerations, and the entire country [21-23].

Fairness and efficiency are the most basic principles followed in the allocation of public resources, serving as important guidance and support for achieving the equalization of basic public services, the analysis of which plays a crucial role in social and economic development. Xie and Fang measured the fairness of medical resource allocation with the Gini coefficient based on the data related to medical and health resources of 31 provinces in China in 2010, and analyzed the efficiency of medical resource use, and explored the fairness and efficiency of medical resource allocation across provinces based on the DEA model [24]; Zhang et al. used the concentration index and Gini coefficient to analyze the equity of health resources and service allocation and evaluated the efficiency of health resources and service utilization with the DEA model [25]. However, in general, few scholars have been able to draw on any systematic research into the fairness and efficiency of comprehensive public resource indicators at the application level.

Previous literature provides a theoretical and empirical basis for this research, but there are still flaws: ①In terms of research content, more single-type public resources are selected for research, and there is less research on comprehensive public resources that integrate multiple indicators; ②As for the research scale, most of the research pour less attention to the large-scale and multi-regional differences; ③In terms of research methods, previous studies mostly followed the welfare, efficiency, and fairness concepts of welfare economics, with qualitative analysis methods such as historical analysis and questionnaire survey methods. Nonetheless, quantitative analysis modes by constructing mathematical models are rarely witnessed; ④With regard to the research perspective, scholars show a propensity to analyze the fairness of resource allocation, other than taking into account both efficiency and fairness.

Accordingly, from the perspective of fairness and efficiency, 110 cities in the Yangtze River Economic Belt were included in this study as research samples for analysis. First, the entropy method was used to construct the public resource index evaluation system and the public resource benefit index evaluation system to more objectively and comprehensively reflect the degree of public resource possession in various provinces and cities; Second, the non-parametric kernel density estimation and the GIS technology were adopted to reveal the dynamic evolution of public resources and their decomposition items from the Spatio-temporal dimension; Third, the Dagum's Gini decomposition method was used to measure the regional gap and source of the public resource index, revealing the pattern and distribution of the fairness of public resource allocation; In addition, the super-efficiency slacks-based measure (SBM) model was employed to evaluate the efficiency of public resource utilization in various provinces and cities, to further analyze the evolution of regional differences in public resource utilization efficiency; Last but not least, on the basis of empirical research, a coupling analysis of fairness and efficiency was conducted to put forward

research conclusions and policy implications.

2. Research Area and Data Sources

2.1 Research Area

The YREB spans the three major regions of China's east, middle and west, covering 11 provincial-level administrative regions. Based on the principle of data availability and parallelism, a total of 110 research units including 108 prefecture-level cities in 9 provinces and 2 municipalities, Shanghai and Chongqing, in the YREB were selected as the research sample. Moreover, according to the “Outline of the Yangtze River Economic Belt Development Plan”, 110 research units were divided into three major parts: Eastern part, Central part, and Western part, as shown in Figure 1.

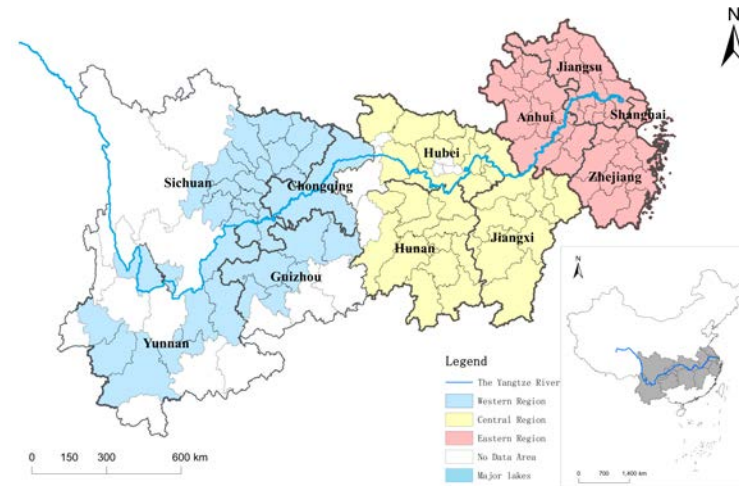


Fig.1 Schematic Diagram of the Research Area of the Yangtze River Economic Belt

2.2 Data Sources

The research data are derived from the “China Statistical Yearbook”, “China City Statistical Yearbook”, “China Health Statistics Yearbook”, and statistical yearbooks of various provinces and cities, etc., with the time spanning from 2007 to 2017. The missing data of individual units are replaced by the moving average of the adjacent three years. Areas, such as Qianjiang and Aba Tibetan and Qiang Autonomous Prefecture, with administrative division adjustments and other changes which resulted in the missing of relevant data, are excluded from the research area (Figure 1). The spatial data are derived from the national geographic information resource catalog service system and the standard map service system. The statistical data are imported into the spatial data attribute table to establish a spatial database. The data processing tools mainly include ArcGIS 10.2, SPSS, etc.

3. Index System and Research Methods

3.1 Selection of Index System

3.1.1 Public Resource Index Evaluation System

The public resource indexes are comprehensive indexes that evaluate the number of public resources in each region. Based on the definition of public resources and the characteristics of social and economic development in the YREB and the calculation process of the entropy method, this study regards infrastructure, social security, education and technology, and medical care as the core content of public resources, and selects 19 indexes such as the number of medical and health institutions per capita to establish a public resource index evaluation system (see Table 1).

Table 1 Public Resource Index Evaluation System

Target	Criterion layer	Index layer	Weight
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layer			hts
Public Resource Evaluation Index	Infrastructure	X1 Railway mileage (km)	0.65 %
		X2 Highway mileage (km)	0.77 %
		X3 Urban road area per capita (square meters)	5.02 %
		X4 Park green area per capita (square meters)	8.95 %
		X5 Total length of public transportation routes (km)	7.56 %
	Social security	X6 Employment rate by region (%)	6.24 %
		X7 Average salary by region (yuan)	10.72 %
		X8 Number of participants in unemployment insurance by region (ten thousand)	7.22 %
		X9 Number of participants in urban basic medical insurance by region (ten thousand)	3.95 %
		X10 Number of urban employees participating in basic endowment insurance by region (ten thousand)	4.74 %
	Education and technology	X11 Technological expenditure in the general budget of local finance (ten thousand yuan)	5.78 %
		X12 Educational expenditure in the general budget of local finance (ten thousand yuan)	3.67 %
		X13 Number of higher education institutions per capita (units/10,000 people)	4.27 %
		X14 Vocational secondary schools per capita (units/10,000 people)	3.54 %
		X15 Number of high schools per capita (units/10,000 people)	2.60 %
		X16 Number of primary schools per capita (units/10,000 people)	4.57 %
	Medical care	X17 Number of medical and health institutions per capita (institutes/10,000 people)	4.39 %
		X18 Number of health personnel per capita (units/10,000 people)	6.66 %
		X19 Number of beds in medical and health institutions per capita (units/10,000 people)	8.73 %

3.1.2 Public Resource Benefit Index Evaluation System

The efficiency of public resource allocation refers to the ratio of the effective total output of regional public resources to the total input under certain production technology conditions [41], which is a comprehensive manifestation of public resource utilization efficiency, utilization status, and management level. The fundamental purpose of public resources is to meet the needs of people's lives and promote social and economic development. Therefore, the study selects four indexes including the regional GDP, etc. to establish a public resource benefit index evaluation system (see Table 2). The public resource benefit index is used to evaluate the utilization efficiency of regional public resources, which forms the input-output index system of the super-efficiency SBM model together with the public resource index evaluation system.

Table 2 Public Resource Benefit Index Evaluation System

Public resource benefit index	Indexes	Weights
	Y1 Regional GDP	21.73%
	Y2 Total retail sales of consumer goods (ten thousand yuan)	19.64%
	Y3 Year-end balance of savings of urban and rural residents (ten thousand yuan)	18.92%
	Y4 General budget revenue of local finance (ten thousand yuan)	16.63%
	Y5 Urbanization rate	23.08%

3.2 Research Methods

3.2.1 Entropy Method

The entropy method is a mathematical method that calculates a comprehensive index based on comprehensively considering the amount of information provided by various factors [26]. In information theory, information entropy is a measure of the degree of disorder in the system, which can measure the amount of effective information provided by data [27-29]. A greater degree of index variation indicates a smaller entropy value, suggesting that the greater amount of information provided by the index results in greater weights of the index [30]. The specific steps of the entropy method to calculate weight are as follows:

There are m evaluation indexes and n evaluation objects, and x_{ij} is the j -th index of the i -th evaluated object. The original data matrix: $X=(x_{ij})_{m \times n}$

First, linear interpolation is used to standardize the decision matrix $X=(x_{ij})_{m \times n}$, namely

$$y_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (1)$$

After standardization, all y_{ij} form a new standardized decision matrix $Y=(y_{ij})_{m \times n}$, followed by defining the entropy of the i -th index:

$$H_i = -\frac{1}{\ln n} \sum_{j=1}^n f_{ij} \ln f_{ij} \quad (2)$$

$$f_{ij} = -\frac{y_{ij}}{\sum_{j=1}^n y_{ij}} \quad (3)$$

In formula (2), H_i is the information entropy of index i . To make $\ln f_{ij}$ meaningful, it is assumed that when $f_{ij}=0$, $f_{ij} \ln f_{ij}=0$.

Finally, the entropy weight of the index is calculated:

$$W_i = -\frac{1-H_i}{m - \sum_{j=1}^m H_i} \quad (4)$$

In formula (4), W_i is the entropy weight of index i , and H_i is the information entropy.

3.2.2 Fairness Index

The fairness index is used to measure the fairness of public resource allocation in the YREB, based on the value of the public resource index, with the reference to the standard deviation of the regional overall public resource index. The formula is:

$$Z = \frac{(x_i - \bar{x})}{\sqrt{\frac{\sum_{i=1}^N (x_i - \bar{x})^2}{N}}} \quad (12)$$

In formula (12), x_i is the public resource index of the i -th province, \bar{x} is the overall public resource index of the YREB, and N is the number of provinces and cities in the YREB.

3.2.3 Dagum's Gini Decomposition Method

Different from the traditional methods of describing the unbalanced variable space such as the Gini coefficient and Theil index [31], Dagum's Gini coefficient not only can decompose the source of the overall regional gap but also solve the problem of overlapping samples between regions, so it can accurately identify the contribution of the gap between regions to the overall gap [32-33]. Therefore, the study adopts Dagum's Gini coefficient to measure the regional gap of the public resource index. The calculation formula of Dagum's Gini coefficient is:

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

In formula (5), y_{ji} (y_{hr}) is the public resource index of i (r) city in j (h) area, n is the number of cities, μ is the average value of public resource index of all cities, k is the number of area divisions.

Formula (5) can be decomposed into the contribution of the regional gap (G_W), the contribution of the net gap between regions (G_{nb}), and the contribution of hypervariable density (G_i), namely G

$$= G_W + G_{nb} + G_i.$$

$$G_{jj} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_j} |y_{ji} - y_{hr}|}{2n_j^2 \mu_j} \quad (6)$$

$$G_W = \sum_{j=1}^k G_{jj} p_j s_j \quad (7)$$

Formulas (6) and (7) are the public resource index gap (G_{jj}) within area j and the contribution of the gap within the area (G_W).

$$G_{jh} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}|}{n_j n_h (\mu_j + \mu_h)} \quad (8)$$

$$G_W = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} (p_j s_h + p_h s_j) D_{jh} \quad (9)$$

Formulas (8) and (9) are the public resource index gap (G_{jh}) between region j and region h, and the contribution of the net gap between regions (G_{nb}).

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

Formula (10) is the contribution of super variable density (G_t).

In formulas (6), (8), (9), (10), $n_j(n_h)$ is the number of cities in j(h) area, $p_j = \frac{n_j}{n}$, $s_j = \frac{n_j \mu_j}{n \mu}$, D_{jh} is the relative influence of the public resource index between regions j and h.

3.2.4 Super-Efficiency Sbm Model

The DEA method is a non-parametric statistical method proposed by Charnes et al. [34] to evaluate whether the decision-making units with the same type of multiple inputs and multiple outputs are technically effective [35]. It builds a production frontier based on multiple inputs and outputs of decision-making units (DMUs) and measures the relative efficiency of decision-making units [36]. The traditional DEA model fails to consider the influence of input-output slack variables on the reliability of model estimation, with a certain deviation in its efficiency value. Therefore, Tone [37] proposed a super-efficiency SBM model, which not only improves the traditional DEA model's inability to distinguish between multiple effective DMUs but also solves the issue of undesired output [38-39], predominantly handling the relative efficiency ranking problem of DMUs [40]. In this model, this article regarded each province as a DMU, with the mathematical formula of:

$$\begin{aligned} \theta = \text{Min} \theta &= \frac{\frac{1}{m} \sum_{i=1}^m (\bar{x}/x_{ij})}{\frac{1}{s_1+s_2} (\sum_{p=1}^{s_1} \bar{y}^d / y_{pj}^d + \sum_{q=1}^{s_2} \bar{y}^u / y_{qj}^u)} \\ \text{s.t. } \bar{x} &\geq \sum_{j=1, \neq k}^n x_{ij} \gamma_j \quad i = 1, \dots, m \\ \bar{y}^d &\geq \sum_{j=1, \neq k}^n y_{pj}^d \gamma_j \quad p = 1, \dots, r_1 \\ \bar{y}^u &\geq \sum_{j=1, \neq k}^n y_{qj}^u \gamma_j \quad q = 1, \dots, r_2 \\ \gamma_j &\geq 0 \quad j = 1, \dots, n; j \neq 0 \\ \bar{x} &\geq x_k \quad k = 1, \dots, m \\ \bar{y}^d &\geq y_k^d \quad q = 1, \dots, s_1 \\ \bar{y}^u &\geq y_k^u \quad u = 1, \dots, s_2 \end{aligned} \quad (11)$$

In formula (11), x_{ij} and y_{ij} respectively represent the input and output of the j-th DMU; The input and output \bar{x} and \bar{y}^d are the input vector and output vector in the subset \bar{P} of the newly generated possibility excluding (x_0, y_0) , namely $(x_0, y_0) \in \bar{P} (x_0, y_0)$; θ is the efficiency value of the super-efficiency SBM.

4. Spatio-Temporal Evolution Characteristics of Public Resource Allocation

4.1 The Temporal Evolution of Public Resource Allocation

The public resource index evaluation system is used to calculate the panel data corresponding to each city, which is presented in chronological order by province, as shown in Table 3. Moreover, the line graph of the public resource index of each province over time and the evolution trend of the public resource secondary index evaluation index of the three major regions are plotted, and the dynamic evolution of the regional overall public resource allocation is analyzed by the non-parametric kernel density estimation method. See Figure 2.

Table 3 Public Resource Index of Each Province

Region	Province	Year											Mean
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
East	Shanghai	0.674	0.741	0.697	0.560	0.669	0.623	0.595	0.574	0.576	0.602	0.641	0.632
East	Jiangsu	0.506	0.487	0.468	0.518	0.565	0.528	0.547	0.544	0.549	0.556	0.771	0.549
East	Zhejiang	0.481	0.519	0.530	0.435	0.533	0.518	0.550	0.548	0.568	0.568	0.707	0.542
East	Anhui	0.197	0.227	0.257	0.258	0.332	0.307	0.308	0.283	0.293	0.303	0.344	0.283
Central	Jiangxi	0.243	0.249	0.285	0.242	0.276	0.290	0.288	0.321	0.319	0.312	0.326	0.286
Central	Hubei	0.288	0.295	0.339	0.282	0.367	0.345	0.357	0.399	0.374	0.397	0.381	0.348
Central	Hunan	0.279	0.296	0.315	0.300	0.331	0.304	0.295	0.301	0.324	0.312	0.325	0.308
West	Chongqing	0.111	0.201	0.249	0.094	0.269	0.342	0.353	0.319	0.317	0.335	0.376	0.270
West	Sichuan	0.217	0.247	0.283	0.347	0.344	0.359	0.365	0.387	0.362	0.360	0.423	0.336
West	Guizhou	0.228	0.195	0.153	0.257	0.198	0.207	0.241	0.238	0.277	0.296	0.369	0.242
West	Yunnan	0.188	0.174	0.158	0.264	0.197	0.241	0.216	0.219	0.204	0.204	0.250	0.211
Mean		0.310	0.330	0.339	0.323	0.371	0.369	0.374	0.376	0.379	0.386	0.447	

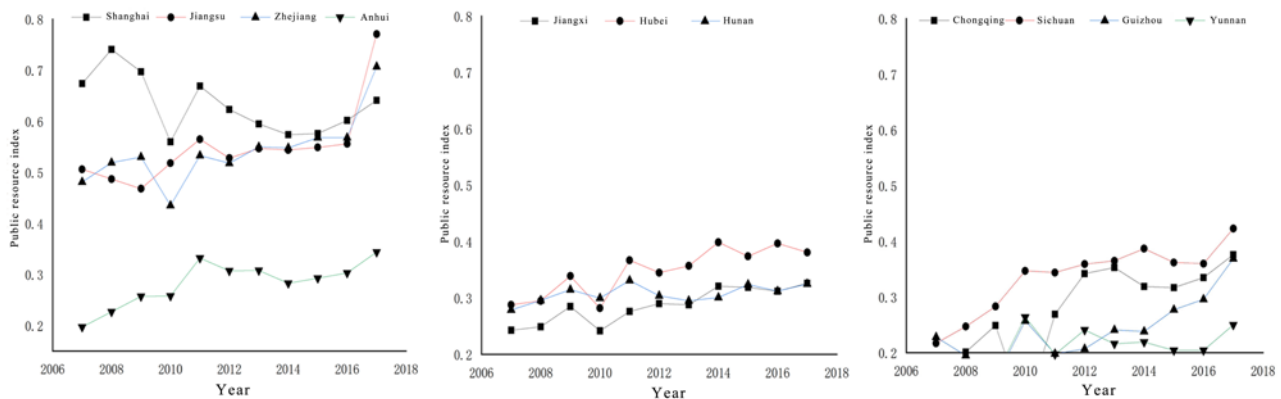


Fig.2 The Dynamic Evolution Trend of the Public Resource Index of Each Province

From 2007 to 2017, the overall public resource index of the YREB has witnessed a stable growth, with an increase of the average index of nearly 44%, from 0.3102 to 0.4467, which embodies China's social and economic development in terms of public resources and public services. From Figure 2, it can be seen that from 2008 to 2012, the public resource index of all provinces in the eastern region saw a drastic decline. The decline was mainly attributed to the exogenous impact of the international financial crisis, leading to the decline of social security indexes such as employment levels and average wages. In the central and western regions during this period, a strong economic stimulus policy implemented by the government, which relied on large-scale

infrastructure investment to promote economic development, has promoted the growth of public resources and facilities, and it accounts for the unexpected rising of the evaluation index. After 2014, China's social development has entered a new normal, shifting from factor-driven and investment-driven rapid growth to a stable growth that focuses on quality and innovation. Coupled with the rapid development of informatization and the digital economy, social public resources have also shown a corresponding increase in fluctuation.

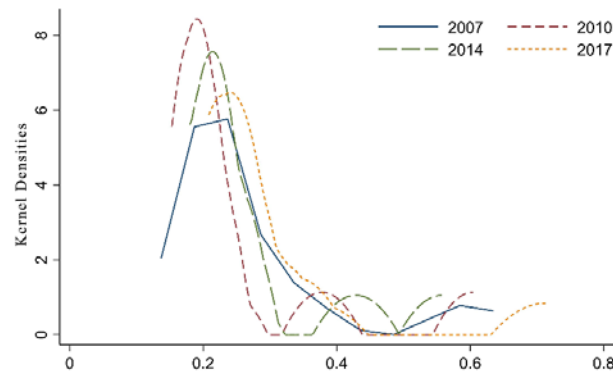


Fig.3 Non-Parametric Kernel Density Distribution of Public Resource Index

Figure 3 shows that the public resources of the provinces and cities in the YREB witness obvious echelon formations, that is, small clusters of high index echelons and high clusters of low index echelons. With time, the nuclear density curve gradually shifts to the right, showing a unimodal distribution, with an overall decreased peak height, a tendency of the left tail of the curve toward the center, and a tailing shape of the right tail deviating from the center. It demonstrates a gradual improvement of the possession of public resources in the YREB, with the number of cities with low evaluation indexes declining and the number of cities with high evaluation indexes rising. High and steep curve peaks are observed in 2010, 2014, and 2017, with the left end truncate and the right end uplifts drastically, which reflects that the number of cities with low public resource index is large and relatively concentrated, while the number of provinces and cities with high-index could not be underestimated. The overall trend has obtained an amelioration compared to 2007.

4.2 The Spatial Evolution of Public Resource Allocation

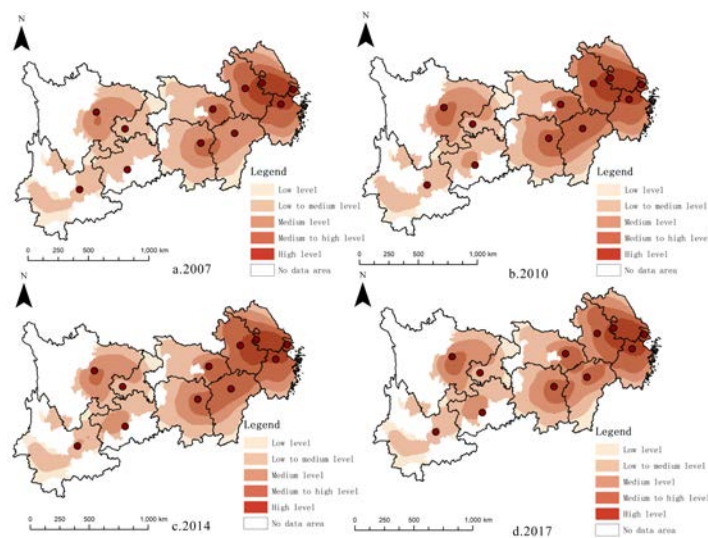


Fig.4 The Spatial Distribution Pattern of the Core Density Value of the Public Resource Index

Through the spatial distribution and change of the core density value of the public resource index, with 2007, 2010, 2014, and 2017 as the baseline, we further explore the changing trend of the public resource possession in each city, as shown in Figure 4. The results show that the high-value areas of the public resource index in 2007 were mainly concentrated in the upper reaches of the

Yangtze River and a few central cities, showing a “single-core and multiple points” spatial structure. The central and western regions were in a state of collapse. Due to the regional imbalance between population, resources, and the environment, the spatial distribution of public resources is similar to the “Caudine Valley”. From 2010 to 2014, regional development strategies such as the regional integration of the Yangtze River Delta and the urban agglomerations in the middle reaches of the Yangtze River have promoted the development of public resources in the middle and upper reaches of the Yangtze River, especially in central cities. It has also enhanced the radiation and leading effect of the central city, which implied a remarkable increase in the possession of public resources in the whole region. In 2017, with the proposal and implementation of the national strategy of the YREB, its spatial distribution pattern presented a circular distribution with the Yangtze River Delta as the core. At the same time, the provincial capitals were taken as the second-tier cores to form a spatial layout of local agglomeration, which realized the upgrade and development of public resource allocation in the central and western areas. During the 11 years, the distribution pattern of public resources in the YREB has generally undergone a development process of “Partially prioritized inconsistent low-level development-multi-point flourishing center-led development-highlighted high-level regional coordinated development.”

5. The Evolution of the Fairness of Public Resource Allocation

5.1 The Evolution of Public Resource Allocation Fairness in Various Provinces and Cities

With the standard deviation of the public resource index of the YREB as a reference, the fairness index of public resource allocation in various provinces is calculated, and the spatial visualization analysis is carried out through ArcGIS, as shown in Figure 5. According to the Jenks natural breakpoint classification, the current state of public resources in various provinces and cities is divided into three levels: over-fairness, fairness, and under-fairness, which represent, in sequence, that the number of public resources in each province is much higher, close to, or far lower than the regional average.

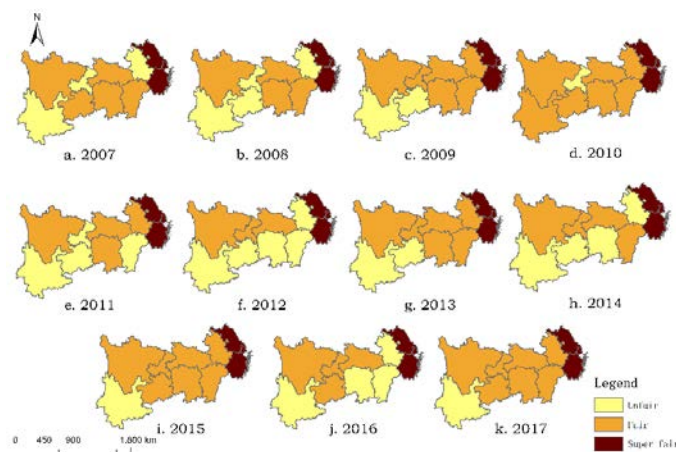


Fig.5 Fairness Evolution of Public Resource Allocation in Various Provinces and Cities

The results show that from 2007 to 2017, Shanghai, Jiangsu, and Zhejiang have always been in a state of over-fairness, Sichuan and Hubei have remained in fairness, while Yunnan in a state of under-fairness; In addition, Anhui and Guizhou have seen continuing improvement in the past eleven years, evolving from a state of under-fairness to fairness, while Chongqing and Hunan had been lingering between the state of fairness and under-fairness, with a general situation of being free from under-unfairness.

Taken together, during these 11 years, the fairness of the public resource allocation in the provinces of the YREB has displayed an apparent echelon and distinct regional gap but with a gradual shrinking trend. The proportion of provinces in the state of fairness continued to rise, that of those in the state of under-fairness was significantly reduced, and the over-fairness provinces showed an agglomeration distribution without changes in the number.

5.2 Regional Gaps and Sources of Public Resource Index

To further explore the reasons behind the unfair allocation of public resources in the provinces and cities of the YREB, the overall regional gap in the allocation of public resources are measured by Dagum's Gini coefficient and decomposed according to the spatial scale of the three major regions of east, central, and west to reveal the main sources of regional gaps. The measurement is based on the public resource index and the panel data of the sub-indexes of infrastructure, social security, education and technology, and medical and health.

Table 4 reports the regional gap and its decomposition results of the public resource index of the YREB from 2007 to 2017. It can be seen from that, in general, the Dagum's Gini coefficient presented a two-stage inverted “V”-shaped evolution trend. In the first stage, the regional differences in the allocation of public resources have been witnessing an elevation, from 0.1952 in 2007 to the maximum value of 0.2283 in 2010, before a long period of fluctuation in the second stage, and then dropped to 0.1958 in 2017. On the one hand, during the entire inspection period, the overall average Gini coefficient was 0.2005, remaining at the average level in international practice (0.2~0.3), which reflected the implementation of China's concept of social justice in economic and social development; on the other hand, the gap in the possession of public resources in the YREB has seen a slight increase, with minor growth rate. The changes in the overall Gini coefficient are highly consistent with the Spatio-temporal evolution of the public resource allocation described above.

Table 4 Dagum's Gini Coefficient of the Public Resource Index and Its Decomposition Results

Year	Overall Gini coefficient	Gini coefficient within the region			Gini coefficient between regions			Within the regions	Contribution rate	super variable density
		East	Central	West	East-central	East-west	Central-west			
2007	0.1952	0.2122	0.0118	0.1497	0.2379	0.2563	0.1162	27.66%	61.13%	11.22%
2008	0.2003	0.2322	0.0039	0.1059	0.2667	0.2688	0.0903	26.43%	67.03%	6.54%
2009	0.2021	0.2451	0.0081	0.1199	0.2584	0.2655	0.0953	28.09%	69.11%	2.80%
2010	0.2283	0.2445	0.0448	0.1952	0.2513	0.2917	0.1601	29.34%	64.23%	6.43%
2011	0.1847	0.2270	0.0099	0.1070	0.2361	0.2473	0.0831	27.94%	70.34%	1.71%
2012	0.1940	0.2332	0.0075	0.1223	0.2580	0.2455	0.0973	28.18%	65.13%	6.69%
2013	0.1879	0.2271	0.0114	0.1195	0.2503	0.2388	0.0916	28.34%	62.16%	9.50%
2014	0.2014	0.1947	0.0640	0.1892	0.2236	0.2474	0.1608	29.15%	67.87%	2.97%
2015	0.2019	0.2432	0.0111	0.1365	0.2670	0.2485	0.1091	28.88%	66.45%	4.67%
2016	0.2135	0.2688	0.0159	0.1272	0.2823	0.2598	0.1156	29.16%	67.81%	3.03%
2017	0.1958	0.2565	0.0255	0.1012	0.2661	0.2417	0.0939	29.06%	68.85%	2.09%

It is worth noting that during the entire investigation period, the inter-regional Gini coefficient exceeded the intra-regional and super variable-density Gini coefficients, indicating the inter-regional gap as the main contributory factor for the overall regional gap in the possession of public resources in the YREB. Among the inter-regional gaps, the ones between the eastern region and the central region, and between the eastern region and the western region were the main sources of such gaps. Variations of the coefficient values between the eastern part and the central and

western part stood out in the intra-regional comparison, demonstrating an objective existence of the large intra-regional gap in the public resource allocation and a relatively balanced state of resources deficiency in the central and western regions due to the low public resource index.

The average contribution rates of the intra-regional gap, inter-regional gap, and super variable density to the overall gap were 28.38%, 66.37%, and 5.25%, respectively. The excessively higher contribution rate of the inter-regional gap than that of intra-regional and super variable density further verified the inter-regional disparity as the major source of the overall regional gap. In addition, the rather weak contribution rate of the super variable density compared with the inter-regional and intra-regional contribution rate indicated the minor impact of the overlap factors among different regions on the overall regional gap.

6. The Characteristics of the Evolution of Public Resource Allocation Efficiency

6.1 The Efficiency Evaluation of Public Resource Allocation in Various Provinces and Cities

The evaluation of the public resource allocation efficiency of provinces and cities in the YREB from 2007 to 2017 is conducted by the super-efficiency SBM model. The average value of public resource allocation efficiency in various provinces and cities was ranked in Table 5, with the public resource index as the input index and the public resource benefit index as the output index. In general, the efficiency of public resource allocation in the YREB has experienced two periods of rising from 2007 to 2011 and 2012 to 2016, with the average overall allocation efficiency from 0.2688 to 0.7824, emphasizing a propensity of the overall public resource allocation for highly efficient development.

Table 5 Public Resource Allocation Efficiency Values of the Provinces in the Yangtze River Economic Belt

Regions	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Mean
Jiangsu	0.354 4	0.405 7	0.491 4	1.152 9	1.101 2	0.707 5	0.755 1	0.870 5	1.008 0	1.043 6	0.805 0	0.790 5
Anhui	0.361 7	0.329 7	0.343 3	1.033 3	0.572 4	0.455 4	0.550 9	1.011 4	0.892 4	1.155 2	1.074 6	0.707 3
Sichuan	0.290 8	0.343 4	0.354 7	0.528 5	1.042 8	0.508 5	0.604 9	0.587 1	1.005 3	1.022 6	1.031 3	0.665 4
Guizhou	0.136 9	0.265 9	0.401 4	0.341 6	1.058 2	0.610 0	0.652 9	1.051 8	1.051 6	1.001 4	0.277 7	0.622 7
Chongqing	0.479 5	0.292 1	0.271 6	1.502 4	0.712 2	0.397 0	0.358 8	0.597 4	1.021 7	0.493 8	0.453 7	0.598 2
Hunan	0.213 4	0.238 6	0.305 0	0.493 8	0.455 3	0.484 4	0.569 7	0.791 1	0.734 7	1.052 2	1.036 6	0.579 5
Shanghai	0.307 3	0.192 5	0.226 3	1.488 5	0.464 3	0.319 0	0.364 2	0.481 3	0.582 2	0.644 8	1.244 3	0.574 1
Zhejiang	0.271 8	0.308 4	0.319 9	0.520 5	1.044 7	0.497 3	0.528 5	0.569 1	0.616 0	0.786 1	0.689 8	0.559 3
Hubei	0.177 2	0.221 6	0.226 4	0.436 5	0.464 7	0.410 9	0.505 6	0.479 4	0.798 7	0.796 5	0.882 4	0.490 9
Yunnan	0.177 2	0.263 3	0.306 4	0.217 7	0.405 4	0.238 0	0.322 0	0.498 2	0.612 0	1.119 2	0.490 5	0.422 7
Jiangxi	0.165 1	0.232 3	0.257 4	0.324 7	0.430 3	0.312 6	0.374 5	0.386 5	0.542 3	0.852 9	0.620 7	0.409 0
Mean	0.266 8	0.281 2	0.318 5	0.730 9	0.704 7	0.449 1	0.507 9	0.665 8	0.805 9	0.906 2	0.782 4	0.583 6

Theoretically, the efficiency of public resource allocation revealed the alignment of public resource input and output, yet, in fact, reflected the degree of integration and coordination of local public resources and social and economic development. It can be seen from the table that for Jiangsu, Anhui, Sichuan, and Guizhou, there were 4 years out of 11 during which the allocation efficiency of public resources in provinces exceeded 1, indicating an effective state of resource allocation; Chongqing, Hunan, Zhejiang, Shanghai, and Yunnan also witnessed years of effective

resource allocation with efficiency values exceeding 1. However, though years with efficiency values exceeding 1 were absent for Hubei and Jiangxi, which is considered ineffective allocation efficiency, their allocation efficiency still showed relatively notable growth.

6.2 Coupling Analysis of the Efficiency and Fairness of Public Resource Allocation in Various Provinces

Given the above research on fairness and efficiency, the efficiency index of the public resource allocation of each province is derived from the comparison results of the standard deviation of the public resource allocation efficiency value and the difference between the average value of the public resource allocation efficiency of the YREB and the public resource allocation efficiency value of each province. The average fairness-efficiency coupling analysis diagrams of each province in 2007 and 2017, and through 11 years, are plotted, with the fairness index as the X-axis and the efficiency index as the Y-axis, as shown in Figure 6.

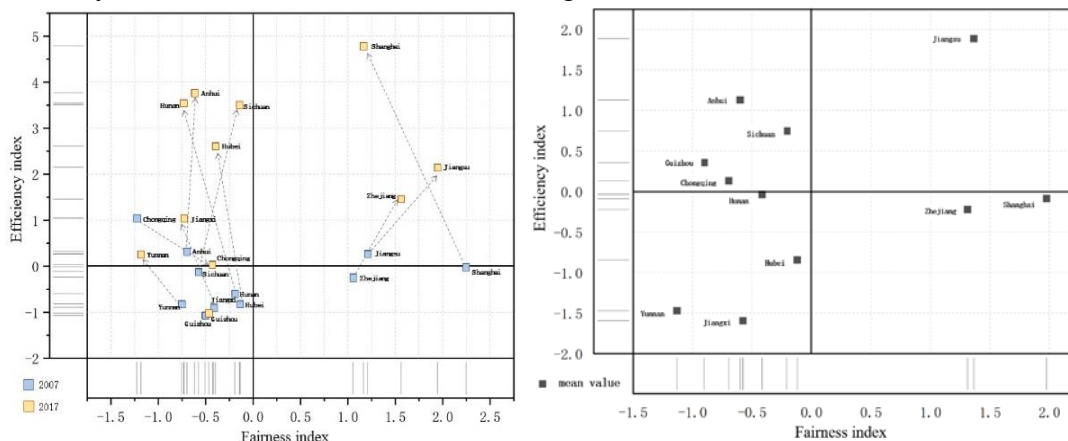


Fig.6 Analysis of the Coupling of Fairness and Efficiency in Each Province

From the changes in coupling points from 2007 to 2017, the movement of Jiangsu, Zhejiang, Sichuan, and Anhui toward the first quadrant presents an evolutionary characteristic of fairness and efficiency in the allocation of public resources. The movement of Shanghai, Hubei, Hunan, Jiangxi, and Yunnan toward the second quadrant indicates a significant increase in the efficiency index, with a descending trend in their relative public resource possession. Chongqing has witnessed a trend of decreasing relative allocation efficiency and increasing relative public resource possession. In addition, no marked changes have been obtained in Guizhou.

Results of the coupling analysis of the average value of each province index in 11 years demonstrate that among the 11 provinces, Jiangsu is in its own league of public resource possession and allocation efficiency, indicating a best fairness-efficiency coupling of public resources in the social development of the region. The positive efficiency index and negative fairness index of Anhui, Sichuan, Guizhou, and Chongqing reveals the high region's allocation efficiency but insufficient public resource input. Located in the Yangtze River Delta, Jiangsu and Anhui are important provinces with abundant social resources per capita and rapid economic development. Sichuan, rich in humanities and natural resources, has rapidly developed into a paramount growth pole for the economic and social development of the western region in recent years, driven by the radiation of the Chengdu-Chongqing urban circle. Despite the location in the western region and the rather backward level of social and economic development, Guizhou has also acquired a satisfactory effective total output which is considered effective public resources allocation, due to its large-scale economic infrastructure construction and rapid development of digital industrial transformation. To upgrade the output of social and economic benefits, the increase of the input of public resources, the improvement of regional fairness index, and the maximum advantage of allocation efficiency should be prioritized in the above provinces and regions.

Furthermore, the excessively high possession of public resources accompanied by the contrasting low effective output of Shanghai and Zhejiang, which is reflected by the extremely high fairness index and negative efficiency index, illustrates the redundant input and deficient output.

Accordingly, modifications of the resource structure and resource input are required in these regions to increase the corresponding output and optimize the efficiency of allocation.

The negative fairness index and efficiency index of Hunan, Hubei, Jiangxi, and Yunnan, especially in Jiangxi and Yunnan, shows an overwhelmingly poor degree of fairness-efficiency coupling. Among these provinces, Yunnan is located on the southwest border with a weak foundation for social and economic development, and, therefore, it has a relatively inefficient development. The low efficiency in the allocation of public resources of Hubei, Hunan, and Jiangxi in the central region is constrained by the huge population, arduous development and transformation, and high energy-consuming industrial structure. In short, what resides in the low efficiency of some regions is the structural deviation between public resource input and local economic development.

7. Conclusion and Discussion

7.1 Main Conclusion

In this study, regarding the panel data of 110 cities in the YREB from 2007 to 2017, policy guidance, and preliminary research, a public resource index evaluation system and a public resource benefit index evaluation system were constructed using the entropy method. The Spatio-temporal evolution of public resource allocation, regional gap, and allocation efficiency were measured and analyzed by spatial visualization, Dagum's Gini decomposition method, and super-efficiency SBM model. The main conclusions are as follows:

(1) The overall public resource possession in the YREB showed a fluctuating upward trend, with an increase of average index close to 44%, from 0.3102 to 0.4467; The non-parametric kernel density distribution map showed a gradual improvement of the quantitative structure of evaluation indexes, which was reflected by a decrease of the number of cities with low evaluation indexes and an elevation of the number of cities with high evaluation indexes. In terms of spatial distribution, the distribution of public resources presented a circle-layered distribution with the Yangtze River Delta as the core and provincial capital cities as the secondary core, forming a spatial layout of local clusters. During the 11 years, the spatial allocation of public resources in the Yangtze River Economic Belt has undergone a development process of “Partially prioritized inconsistent low-level development-multi-point flourishing center-led development-focused high-level regional coordinated development.”

(2) During the 11 years, the fairness of the public resources allocation in the provinces of the YREB has displayed an apparent echelon and distinct regional gap. Shanghai, Jiangsu, and Zhejiang were in a constant state of over-fairness, Sichuan and Hubei were in the state of fairness, Yunnan was in a state of under-fairness, and Anhui, Guizhou, Chongqing, and Hunan have evolved from under-fairness to fairness.

(3) The Dagum's Gini coefficient of the public resource allocation in the YREB presented an inverted “V”-shaped evolution trend, indicating a minor increase of the regional gap, with an overall Gini coefficient of 0.2005. The overall regional disparities were mainly caused by inter-regional disparities, in which the disparities between the eastern region and the central region, as well as between the eastern region and the western region, were the major factors of regional unfairness.

(4) The efficiency of public resource allocation in the YREB has experienced two rises from 2007 to 2011 and 2012 to 2016, with the average overall allocation efficiency increasing from 0.2688 to 0.7824. This suggested a tendency toward highly efficient development of overall public resource allocation in the region. Results of the coupling analysis of fairness and efficiency revealed a superior degree of coupling between fairness and efficiency in Jiangsu, Anhui, and Sichuan and a comparatively high resource allocation efficiency in Guizhou and Chongqing, which requires further input of public resources. Active adjustment of resource structure and resource input should be prioritized in Zhejiang and Shanghai to increase corresponding social and economic output. However, Hunan, Hubei, Jiangxi, and Yunnan observed poor fairness-efficiency coupling. What resides in the low efficiency of some regions is the structural deviation between public resource

input and local economic development.

7.2 Discussion

The principle of fairness and efficiency is the basic principle of the allocation of public resources and an important connotation of the reasonable allocation of public resources [42]. It aims to pursue the maximization of its social value, meet the resource needs of people from different regions, different levels, and different groups, and advocate space justice and social justice.

Therefore, the following policy enlightenment and recommendations can be derived from the above research conclusions:

First, prioritize increasing public resources investment, improve the public financial system, optimize the quantitative structure of regional public resource distribution, and elevate the regional proportion of the medium public resource index, to form a balanced, efficient, and sustainable regional public resource growth model.

Second, enhance the social security system and strengthen infrastructure construction. The social security gap is a prominent deficiency of the public resources gap. Consequently, It is indispensable to further improve the social security system with social insurance as the main body, adhere to the guidance of the system, and strengthen the construction of the social security system around the goals of full coverage, basic protection, multi-level, and sustainability. Furthermore, according to the actual development of each region, attention should be given to the acceleration of new infrastructure construction, the activation of the high-quality assets of public resources, and the consolidation of the foundation for high-quality economic development.

Third, the government should attach importance to the development gap in the eastern, central, and western regions. This will promote the complementary advantages of the upper, middle, and lower reaches with collaboration and interaction and ensure the equalization of public services. In light of the inter-regional disparities between the three major regions contributing to regional unfairness in the public resource allocation in the YREB, the coordinated, ordered, and healthy development of the economic belt can only be realized by strengthening the top-level design, breaking down administrative barriers, improving the cross-regional cooperation and coordination mechanism, and accelerating the flow of public resource elements and the docking of standards.

Fourth, the results of this study point out the insufficient output as the main source of ineffective allocation in the central region, with apparent characteristics of “low-grade overextension”. Based on steadily increasing the input of public resources, efforts should be made to transform the economic development model and improve the utilization efficiency of public resources. Redundant investment is the key issue to be addressed for the improvement in the eastern region. Given the insufficient utilization of public resource elements and scanty investment in the western region, mutual promotion can be achieved by counterpart assistance, industrial transfer, and resource sharing to contribute to increasing the quantity and quality of public resources in the western region and optimizing the efficiency and production in the eastern region.

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