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Spatial Effects of Health Resource Allocation Efficiency in County TCM Hospitals: Evidence from Zhejiang, China

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ABSTRACT

Due to the lack of research on the efficiency of health resource allocation at the micro level in Zhejiang Province, this study utilized the super-efficiency Slack Based Measure (SBM) model to assess the efficiency of health resource allocation in county-level Traditional Chinese Medicine (TCM) hospitals in Zhejiang Province in 2021. We also constructed three spatial econometric models to investigate the key factors influencing the efficiency. The research findings revealed that the overall health resource allocation efficiency was relatively low and exhibited significant variations across different counties. In order to effectively enhance the efficiency, it is essential to not only prudently regulate the inputs of health resources under the premise of output orientation, but also scientifically manage the total amount of general public budget expenditures, the number of sports venues, and the number of beds in pension service institutions, while fully leverage the spillover effect of efficiency.

1. Introduction

Health represents an inherent entitlement of the human race, and every individual possesses the capacity and opportunity to attain health equity. The reservoir of health resources constitutes an essential compendium of components in the facilitation and advancement of health. Nonetheless, owing to the scarcity of resources, the apportionment of health resources frequently gives rise to issues of inequity, culminating in the manifestation of "health inequity". For example, Ponce et al found that despite decades of research exposing health disparities between populations and communities in the US, health equity goals remain largely unfulfilled [1] .Cunningham et al found that despite a compelling body of evidence and decades of policy recommendations, deep inequities in health persist with historically marginalized groups [2]. Simultaneously, Yi et al argues that China's investment in medical and health resources is generally ineffective, which is why, despite the expenditure on public medical and health has increased greatly in China, the problems as low efficiency and health inequity still exist [3].

As early as 1977, the World Health Organization (WHO) proposed the strategic objective of "Health for All by the Year 2000" to address the significant inequities in the distribution of health resources [4]. While access to basic healthcare services has improved for many individuals in developing nations like India, Bangladesh, Nepal, China, etc.[5][6][7], global health inequity persist, and not all countries worldwide are capable of achieving efficient allocation of health resources. For example, Radojicic et al found in their study of health efficiency of 38 Organization for Economic Co-operation and Development (OECD) member countries that Slovenia is the only OECD country that was effective in both analysis years [8]. Alcalde-Rabanal et al identified significant differences in health promotion efficiency and effectiveness scores among Healthy Environments and Communities Program (HECP) communities in 32 Mexican states [9]. This emphasizes the continued need for each country to prioritize and strive to achieve equal allocation of global health resources.

China, as the largest developing country globally, has actively responded to the WHO's call. It is not only focused on the gap between its own healthcare system and that of other countries worldwide but is also dedicated to enhancing the efficiency of health resource allocation to contribute to global efforts in achieving health equity [10][11]. For instance, research by Meng et al has highlighted the spatial agglomeration characteristics of health technicians at the provincial level in China, along with its significant spatial spillover effects [12]. Mei et al found that while the efficiency of primary medical and healthcare institutions in China is improving, the overall efficiency remains relatively low with notable regional disparities, and the distribution of efficiency indicates higher levels in the eastern and southern regions, and lower levels in the western and northern regions [13].

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As one of the most economically developed provinces in China, Zhejiang Province exerts a significant economic, technological, and cultural influence in the country. It demonstrates strong comprehensive strength and competitiveness in fields such as people's livelihood security, economic development, and environmental protection [14]-[17]. This makes it an important engine of China's economic development, thereby necessitating greater attention to and guaranteeing the health status of its residents. Numerous studies on the inter-provincial efficiency of health resource allocation in China show that Zhejiang Province is often one of the most efficient provinces in the country [18]-[20].

Many scholars have conducted targeted analyses for specific provinces in China with inefficient health resource allocation. For example, Gong et al studied the efficiency of health resource allocation in Sichuan Province [21], Su et al analyzed the equity and efficiency of health resource allocation in public hospitals in Guangdong Province [22], Yang et al assessed the efficiency of resource allocation in Taiwan hospitals. Recently, there has been an increasing number of scholars studying the efficiency of health resource allocation in TCM hospitals [23]. For instance, Li and Wei summarized the development of TCM medical services by analyzing the efficiency of TCM hospitals in 31 provinces of China [24], and Li et al studied the efficiency of medical resources in Gansu municipal TCM hospitals [25].

However, few scholars have specifically researched the health resource allocation status in Zhejiang Province, which is known for its high efficiency of health resource allocation. This research gap may be attributed to the negligence of studying the allocation of health resources in efficient regions and the lack of specific research data provided by micro individuals in Zhejiang Province. As a result, there are limited literature materials analyzing the overall allocation of health resources in various counties of Zhejiang Province at a macro level [26], without delving into detailed research on the differences in the efficiency of health resource allocation at the micro-level, particularly in county-level TCM hospitals in Zhejiang Province.

In order to showcase the efficiency of health resource allocation at the micro level in Zhejiang Province, and conduct an analysis of health resource allocation in county-level TCM hospitals in Zhejiang Province, as well as propose specific improvement measures to enhance the efficiency of health resource allocation in county-level TCM hospitals in Zhejiang Province, this study utilized Matlab, and Stata in combination with the super-efficiency SBM model to assess the health resource allocation efficiency of the county-level TCM hospitals in Zhejiang Province in 2021. Furthermore, after using the Moran test to determine its spatial correlation, this study developed spatial econometric models based on the inverse distance square matrix to analyze the factors influencing the efficiency of health resource allocation in county-level TCM hospitals. Lastly, scientific references were proposed to enhance the efficiency of health resource allocation in county-level TCM hospitals in Zhejiang Province.

2. Material and methods

2.1. Data sources and indicators selection

In this research, 71 county-level administrative regions with public TCM hospitals in Zhejiang Province were chosen (the specific numerical labels and names of each administrative region were presented in Table 2), and the public TCM hospitals in these administrative regions in 2021 were considered as the fundamental research unit.

This study is grounded in the medical production function theory and draws upon established scholarly work to construct a comprehensive input-output framework [25][27][28]. The input dimension encompasses human capital (health technical personnel, physicians, pharmacists, and nurses), physical capital (clinical departments and open beds), and financial capital (fiscal appropriations and total revenue). The output dimension comprises service volume (outpatient visits and discharged patients) and operational sustainability (total revenue). Although contemporary evaluation frameworks advocate for incorporating undesirable outputs—such as average outpatient and inpatient expenses or antibiotic utilization rates—into efficiency assessment, the exclusion of these indicators is necessitated by the unavailability of such granular data at the county level.The specific data for each input and output indicator was extracted from the official 2021 Compilation of Health Resource Data of TCM Hospitals in Zhejiang Province released by the Zhejiang Provincial Health Commission.

The analysis indicators for the influencing factors on the efficiency of health resource allocation were based on the studies of scholars such as Yi, Meng, Zhang, etc.[12][29][30], and included 10 indicators such as annual resident population, PGDP, general public budget expenditures, etc. The data for each influencing factor indicator was collected from the 2021 Zhejiang Statistical Yearbook. Detailed indicators can be found in Table 1.

Table 1 Descriptive statistics of indicators

Dimension	Indicators	Mean	Std. dev.	Minimum	Maximum
Input	Number of health technicians (person)	440.12	240.88	27.00	1120.00
	Number of physicians (person)	164.94	93.57	15.00	416.00
	Number of pharmacists (person)	34.69	17.12	0.00	75.00
	Number of registered nurses (person)	197.41	126.04	5.00	614.00
	Number of clinical departments (unit)	25.25	9.00	6.00	54.00
	Actual number of open beds (unit)	321.21	198.92	0.00	1032.00
	Financial allocation income (1000yuan)	45982.76	48092.94	700.00	229020.00
Output	Total income (1000yuan)	266855.40	175873.20	1953.00	873452.00
	Number of diagnosed and treated patients (person)	494928.90	269759.40	5837.00	1075796.00
	Number of discharged patients (person)	10680.25	7494.06	0.00	35647.00
Efficiency of Health Resource Allocation in TCM Hospitals		0.87	0.60	0.17	3.73
Influencing factors	Annual resident population (10000 unit)	71.36	44.46	6.71	205.60

Dimension	Indicators	Mean	Std. dev.	Minimum	Maximum
	PGDP (yuan)	102372.80	46367.22	40410.00	283463.00
	General public budget expenditures (billion yuan)	94.51	55.56	30.74	324.23
	Number of sports venues (unit)	2328.85	1240.26	315.00	5801.00
	Number of general hospitals (unit)	15.35	12.12	2.00	76.00
	Number of general hospital beds (unit)	3172.99	2844.46	225.00	19718.00
	Number of doctors of general hospitals (person)	2334.18	1695.72	231.00	9464.00
	Number of pension service institutions (unit)	21.25	12.72	4.00	58.00
	Number of beds in pension service institutions (unit)	3218.44	1970.57	387.00	9032.00
	Elderly population coefficient (%)	24.16	3.80	17.66	37.27

Note: Elderly population coefficient is calculated by dividing the population aged 60 and above by the total population, and then multiplying by 100%.

2.2. Data envelopment analysis

Tone first proposed the SBM model in 2001 [31], which was based on the farthest distance to the front function. The SBM model offers an advantage over traditional radial models like CCR and BCC by integrating the relaxation variable problem into inefficiency measurement. Furthermore, in the analysis of DEA models, it is common to have multiple DMUs identified as effective. This poses a challenge as traditional DEA models yield maximum efficiency values of 1 for all effective DMUs, making it difficult to distinguish further between different efficiencies. In order to solve this problem, Tone proposed the super-efficiency SBM model in 2002 [32], which has been widely used in various efficiency studies by scholars. The efficiency model for health resource allocation in this study is constructed based on the super-efficiency SBM model with variable returns to scale:

$$\rho = \min \frac{\frac{1}{m}\sum_{i=1}^{m}\overline{x_i}/x_{i0}}{\frac{1}{s}\sum_{k=1}^{s}\overline{y_k}/y_{k0}}\ \text{s.t.}\begin{cases}\overline{x_i} \geq \sum_{j=1,j\neq 0}^{n}\lambda_j x_j,\forall i\\ \overline{y_k} \leq \sum_{j=1,j\neq 0}^{n}\lambda_j y_j,\forall k\\ \overline{x_i} \geq x_{i0}, y_{k0} \geq \overline{y_k} \geq 0, \lambda_j \geq 0, \sum_{j=1,j\neq 0}^{n}\lambda_j = 1, \forall i,j,k\end{cases} \qquad formula\ (1)$$

This research involves assessing the efficiency of health resource allocation across 71 research DMU (x_0, y_0), with each county-level TCM hospital serving as a DMU. As shown in formula (1), ρ signifies the efficiency of the DMU, where the efficiency greater than 1 indicates effectiveness, and an efficiency less than 1 denotes ineffectiveness. Each DMU has i types of inputs x_i (i=1, 2, ...,7), k types of outputs y_k (k=1,2,3), $\overline{x_i}$ and $\overline{y_k}$ represent the average of all inputs and outputs respectively. n represents the number of DMUs, j represents the j-th DMU, m and s represent the number of input and output variables, i represents the i-th input, k represents the k-th output, λ is the weight, and $\sum_{j=1,j\neq 0}^{n}\lambda_j = 1$denotes variable returns to scale.

2.3. Spatial auto-correlation

The spatial weight matrix illustrates the level of interdependence among geographical or economic attribute values of spatial section units, serving as a crucial connection between the spatial econometric model in theoretical analysis and the actual spatial effects in the real world [33]. Therefore, the choice of spatial econometric model must be based on the suitable spatial weight matrix. In this study, an inverse distance square matrix was constructed by computing the surface distance of latitude and longitude positions, and was employed as the weight matrix. The form of the matrix is as follows:

$$W_{ij} = \begin{cases}1/d_{ij}^2 & i \neq j\\ 0 & i = j\end{cases} \qquad \text{formula (2)}$$

In formula (2), d_{ij} represents the distance between county i and j, and W_{ij} represents the spatial weight matrix between county i and j. There are two types of spatial auto-correlation: global and local. Global spatial auto-correlation can examine the overall spatial distribution pattern of health resource allocation efficiency in 71 county-level TCM hospitals in Zhejiang Province, and indicate spatial dependence; Local spatial auto-correlation can specifically reflect the degree of spatial correlation between efficiency values in each county and neighboring regions, and can identify the contribution of efficiency observations in each spatial unit. The most commonly used global spatial auto-correlation test is the Moran's Index:

$$\text{Moran's Index} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}(x_i-\overline{x})(y_i-\overline{y})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}} \qquad \text{formula (3)}$$

In formula (3), $S^2 = \frac{\sum_{i=1}^{n}(x_i-\overline{x})}{n}$ represents sample variance; n represents the number of counties, x_i, y_i represents the efficiency of health resource allocation in county-level TCM hospitals, $\overline{x}$, $\overline{y}$ represent the mean efficiency; w_ij represents (i,j) element in the spatial weight matrix, and $\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}$ represents the combination of all spatial weight matrices. The value range of Moran's Index is generally between −1 and 1. When Moran's Index > 0, it indicates positive spatial correlation. The larger the value, the more pronounced the spatial correlation. When Moran's Index < 0, the spatial correlation is negative. The smaller the value, the greater the spatial difference. When Moran's Index = 0, the space presents randomness. Furthermore, the Moran scatter diagram is used to reflect the characteristics of local spatial agglomeration, the four quadrants of Moran scatter diagram are used to identify the relationship between an area and its neighbors. The first and third quadrants represent positive spatial auto-correlation, indicating a similar value agglomeration feature; the second and fourth quadrants represent negative spatial auto-correlation, indicating an opposite value agglomeration feature.

2.4. Spatial econometrics model

The spatial econometrics model addresses the deficiency of traditional econometric models in accounting for spatial correlation arising from geographical distance. It not only assesses the direct impact of influencing factors within a particular region, but also evaluates the spillover effect on adjacent regions, that is, the influence of independent variables from other regions on the local dependent variable. The model is expressed as follows:

$$Y_{it} = \rho w_i Y_t + \beta X_{it} + \theta D_i X_t + \mu_i + \gamma_t + \varepsilon_{it}\ ,\varepsilon_{it} = \lambda w_i \varepsilon_t + \nu_{it} \qquad \text{formula (4)}$$

In formula (4), Y_{it} represents the efficiency of health resource allocation in county-level TCM hospital, X_{it} is an N*N order explanatory (exogenous) variable matrix, and w_i is the i-th row of the N*N order spatial weight matrix; $\theta D_i X_t$ represents the spatial weight lag term of the independent variable, ρ is the spatial auto-regressive coefficient, β is the regression coefficient of the independent variable, θ is the spatial regression coefficient of the independent variable, λ is the spatial error regression coefficient, μ_i represents individual effects, γ_t is the time effect, v_{it} is a random interference term that follows independent and same steps, i represents province, and t represents year.

If $\lambda=0$ and $\theta=0$, the spatial econometrics model becomes the Spatial Auto-Regression (SAR) model, which demonstrates the influence of health resource allocation efficiency in county-level TCM hospitals in other regions and the independent variables on the efficiency of the focal region. If $\rho=0$ and $\theta=0$, it transforms into the Spatial Error Model (SEM), which shows the influence of other spatial disturbance variables and the independent variables on the health resource allocation efficiency in county TCM hospitals, excluding spatial independent variables. If $\theta=0$, it represents the spatial auto-correlation model, encompassing spatial lag models and spatial error models. If $\lambda=0$, it becomes the Spatial Dubin Model (SDM), simultaneously considering the spatial lag correlation of the independent variable and the spatial lag correlation of the dependent variable, both with the influence of health resource allocation efficiency in county-level TCM hospitals in other regions on the efficiency of the focal region.

3. Results

3.1. Efficiency calculation results

This research evaluates the efficiency of health resource allocation in 71 county-level TCM hospitals in Zhejiang Province in 2021, based on the super-efficiency SBM model with variable returns to scale. The findings revealed that the average efficiency of health resource allocation was 0.871. Among the 71 DMUs, only 29 counties demonstrated effective allocation of health resources in TCM hospitals, representing 40.85% of the total number of DMUs. These included Jiangbei (3.734), Yuhuan (2.997), Haishu (2.847), Gongshu (2.566), Changxing (1.216), Zhuji (1.184), Kecheng (1.148), Jindong (1.142), Songyang (1.117), Fenghua (1.098), and other areas. The remaining 42 research subjects were found to be ineffective, indicating that 59.15% of the regions have ineffective allocation of health resources, including Wencheng (0.174), Haining (0.347), Yueqing (0.350), Qingyuan (0.353), Daishan (0.377), Wenling (0.380), Rui'an (0.382), Jinyun (0.434), Wuyi (0.445), Sanmen (0.448), etc., as detailed in Table 2.

Table 2 Efficiency of TCM hospitals in various regions

ID	Regions	Efficiency	ID	Regions	Efficiency
1	Gongshu	2.566	37	Shangyu	1.015
2	Xiaoshan	1.089	38	Xinchang	0.657
3	Fuyang	0.744	39	Zhuji	1.184
4	Lin'an	1.034	40	Shengzhou	0.678
5	Linping	1.046	41	Jindong	1.142
6	Tonglu	0.607	42	Wuyi	0.445
7	Chun'an	0.557	43	Pujiang	0.596
8	Jiande	0.556	44	Pan'an	0.464
9	Haishu	2.847	45	Lanxi	0.459
10	Jiangbei	3.734	46	yiwu	1.026
11	Beilun	0.819	47	Dongyang	1.008
12	Zhenhai	1.019	48	Yongkang	0.624
13	Yinzhou	0.704	49	Kecheng	1.148
14	Fenghua	1.098	50	Qujiang	1.007
15	Xiangshan	1.001	51	Changshan	1.003
16	Ninghai	0.814	52	Kaihua	0.473
17	Yuyao	0.686	53	Longyou	0.671
18	Cixi	1.042	54	Jiangshan	0.581
19	Ouhai	0.573	55	Daishan	0.377
20	Yongjia	0.521	56	Shengsi	1.005
21	Pingyang	0.550	57	Huangyan	1.042
22	Cangnan	0.525	58	Luqiao	0.485
23	Wencheng	0.174	59	Sanmen	0.448
24	Taishun	0.540	60	Tiantai	0.750
25	Rui'an	0.382	61	Xianju	1.036
26	Yueqing	0.350	62	Wenling	0.380
27	Jiashan	0.816	63	Linhai	0.516
28	Haiyan	0.816	64	Yuhuan	2.997
29	Haining	0.347	65	Qingtian	0.473
30	Pinghu	0.539	66	Jinyun	0.434
31	tongxiang	1.070	67	Suichang	0.512
32	Nanxun	1.025	68	Songyang	1.117
33	Deqing	0.561	69	Yunhe	1.013
34	Changxing	1.216	70	Qingyuan	0.353
35	Anji	1.003	71	Longquan	1.081
36	Keqiao	0.676		Mean	0.871

3.2. Spatial correlation test

From the perspective of global spatial auto-correlation,as shown in Table 3, the Moran's Index of the health resource allocation efficiency of the 71 county-level TCM hospitals in Zhejiang Province in 2021 was positive (0.131), and passed the significance level test of 1%, indicating that the health resource allocation efficiency of these counties exhibits significant spatial correlation characteristics in spatial distribution.

Table 3 Global Moran's Index

Moran's I	Z	P-value
0.131***	3.595	0.000

Note: * P-value<0.1, ** P-value<0.05, *** P-value<0.01

This paper aimed to examine the spatial correlation of a particular area by creating a Moran scatter plot to analyze the local spatial auto-correlation of health resource allocation efficiency in county-level TCM hospitals in Zhejiang Province. As shown in Figure 1, each data point on the scatter plot represents a DMU.

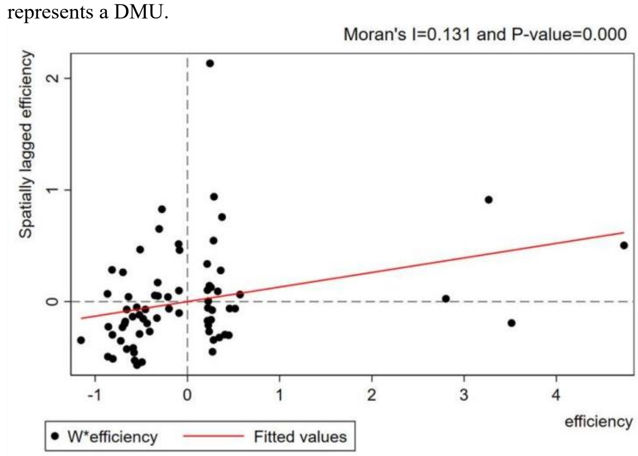

Figure 1 Moran scatter diagram

The results of the Moran scatter diagram indicate that a majority of the efficiency values for the 71 county-level TCM hospitals in Zhejiang Province in 2021 are situated in the first quadrant (High-High) and the third quadrant (Low-Low), which can indicate that there is a significant positive spatial correlation in the allocation efficiency of health resources among the TCM hospitals in Zhejiang Province. Specifically, 19 scatter points were in the first quadrant and 24 in the third quadrant, accounting for 60.56% of the total sample. Conversely, there were 18 scatter points in the second quadrant and 10 in the fourth quadrant, making up 39.44% of the total sample. The specific county names can be found in Table 4.

Table 4 Cluster test for the health resource allocation efficiency

Spatial Aggregation		Spatial Discretization	
High-High	Low-Low	Low-High	High-Low
Gongshu,	Tonglu,	Fuyang,	Jindong,
Xiaoshan,	Chun'an,	Beilun,	Yiwu,
Lin'an,	Jiande,	Yinzhou,	Dongyang,
Linping,	Ouhai,	Ninghai,	Changshan,
Haishu,	Yongjia,	Yuyao,	Huangyan,
Jiangbei,	Pingyang,	Haiyan,	Sanmen,
Zhenhai, Fenghua,	Cangnan,	Haining,	Wenling,
Xiangshan,	Wencheng,	Pinghu,	Songyang,
Cixi,	Taishun,	Deqing,	Yunhe,
Tongxiang,	Rui'an,	Keqiao,	Longquan (10)
Nanxun,	Leqing,	Xinchang,	
Changxing,	Jiashan,	Shengzhou,	
Anji,	Wuyi,	Pujiang,	
Shangyu,	Pan'an,	Kaihua,	
Zhuji,	Lanxi,	Daishan,	
Kecheng, Qujiang,	Yongkang,	Luqiao,	
Shengsi (19)	Longyou,	Tiantai,	
	Jiangshan,	Linhai (18)	
	Xianju,		
	Yuhuan,		
	Qingtian,		
	Jinyun,		
	Suichang,		
	Qingyuan (24)		

3.3. Optimal Model Selection

This study employs LM and Robust LM tests for preliminary diagnosis of spatial correlation. As shown in Table 5, both LM-lag and LM-error statistics significantly reject the null hypothesis at the 1% level, indicating the coexistence of spatial lag and spatial error effects in the sample, suggesting that both SAR and SEM models may be appropriate. However, simulation analyses by Yang (2015) demonstrate that LM tests based on OLS residuals exhibit significant limitations in selecting spatial econometric models [34], as they can effectively distinguish between SAR and SEM models but fail to determine the optimal model specification. Therefore, this study further estimates the SDM model and compares the goodness-of-fit across different model specifications using the Akaike Information Criterion (AIC) [35] and the Bayesian Information Criterion (BIC) [36] criteria to identify the spatial model form that best fits the sample data.

Table 5 LM test

Test		Statistic	degree of freedom	p-value
Spatial Error	Lagrange multiplier	0	1	1.00
	Robust Lagrange multiplier	6.586	1	0.01
spatial lag	Lagrange multiplier	1.669	1	0.20
	Robust Lagrange multiplier	8.255	1	0.00

The test results in Table 6 confirm that the SDM specification represents the optimal model setting for this study. First, regarding goodness-of-fit indicators, the SDM model exhibits the largest log-likelihood value (-7.69) and the lowest AIC value (59.32) compared to SAR and SEM alternatives, indicating its superior explanatory power for the sample data. Although the BIC criterion, which imposes a more stringent penalty on model complexity, marginally favors the SAR model (105.28) over the SDM model (109.10), this does not constitute sufficient grounds for rejecting the SDM specification. More critically, rigorous degradation tests preclude the possibility of model simplification. The LR test strongly rejects the null hypotheses that the SDM can be reduced to SEM (LR = 49.24, $p < 0.01$) or SAR (LR = 49.55, $p < 0.01$) at the 1% significance level. This finding implies that constraining the exogenous interaction term coefficients to zero (i.e., adopting the SAR model) would introduce substantial specification bias. Therefore, synthesizing the robust conclusions from LR tests with the favorable fit indicated by AIC, this study establishes the SDM model as the baseline specification for accurately assessing the efficiency of health resource allocation in county-level TCM hospitals in Zhejiang Province.

Table 6 Test results based on likelihood functions and degradation testing

Type of test		SDM	SEM	SAR	OLS
Log Likelihood		-7.69	-27.07	-27.22	-51.84
Akaike information criterion		59.32	78.44	78.13	/
Bayesian Information Criterion		109.10	105.59	105.28	/
Degradation testing	Wald's test	/	0.01	76.80	/
	likelihood ratio	/	49.24	49.55	/
	Lagrange multiplier test	/	0.08	8.76	/

3.4. Display of regression results

This study conducts spatial regression analysis on the health resource allocation efficiency of 71 county-level TCM hospitals in Zhejiang Province, with detailed results presented in Table 7. The coefficient for total public budget expenditure is −0.004104, significantly negative at the 10% level, indicating that the expansion of regional public fiscal investment has not concurrently enhanced the resource allocation efficiency of TCM hospitals. Instead, it may generate inhibitory effects due to input redundancy or inefficient utilization. The local effect coefficient for the number of beds in pension service institutions is −0.000078 ($p < 0.1$), suggesting a negative association between increased regional pension beds and TCM hospital efficiency, potentially stemming from structural shifts of medical resources toward elderly care services or configuration distortions arising from functional overlap. However, the spatial lag term coefficient is 0.055829 ($p < 0.01$), significantly positive, demonstrating that the agglomeration of pension beds in neighboring regions exerts positive spillover effects on local TCM hospital efficiency, reflecting the complementarity and collaborative potential of regional medical-elderly care resources. Additionally, the number of sports venues is significantly negatively correlated with the health resource allocation efficiency of TCM hospitals ($p < 0.10$), indicating that increased sports venue construction in the region adversely affects health resource allocation efficiency.

Table 7 Regression results of spatial econometric models

Variable	SDM

	Coefficient	P-value
constant	0.944887**	0.032
End of year resident population	0.001857	0.701
PGDP	-0.000001	0.785
General public budget expenditures	-0.004104*	0.052
Number of sports venues	-0.000184*	0.067
Number of general hospitals	0.013852	0.237
Number of general hospital beds	0.000032	0.682
Number of doctors of general hospitals	0.000127	0.339
Number of pension service institutions	0.005078	0.396
Number of beds in pension service institutions	-0.000078*	0.077
Elderly population coefficient	-0.000400	0.983
W*End of year resident population	-1.634257	0.596
W*PGDP	0.000941	0.141
W*General public budget expenditures	-0.725168	0.547
W*Number of sports venues	0.017461	0.788
W*Number of general hospitals	3.724494	0.446
W*Number of general hospital beds	-0.040567	0.325
W*Number of doctors of general hospitals	0.060116	0.502
W*Number of pension service institutions	-4.717532	0.162
W*Number of beds in pension service institutions	0.055829***	0.002
W*Elderly population coefficient	-3.241770	0.373
ρ	0.999952***	0.000
σ^2	0.145	
R^2	0.597	

4. Discussion

4.1. Coexistence of low efficiency and differences

The findings indicate that the average efficiency of health resource allocation in 71 county-level TCM hospitals in 2021 was only 0.871. This suggests that the overall output of the three indicators of total income, number of diagnosed and treated patients, and number of discharged patients did not meet the expected effect of the seven input indicators including the number of health technicians, physicians, pharmacists, registered nurses, clinical departments, actual open beds, and financial allocation income. Consequently, the overall efficiency of health resource allocation in county-level TCM hospitals in Zhejiang Province is relatively low. Furthermore, the research results revealed that among the 71 TCM hospitals representing different counties, Ningbo Jiangbei District CTM Hospital exhibited the highest efficiency in health resource allocation with a value of 3.734, whereas Wencheng County CTM Hospital had the lowest efficiency at 0.174, showing a significant 21-fold difference. This highlights a substantial gap in health resource allocation efficiency among county-level TCM hospitals in Zhejiang Province. Therefore, the overall health resource allocation efficiency in Zhejiang Province in 2021 was not very high, and displayed noticeable variations across different counties.On a national level, the overall efficiency of health resource allocation in Zhejiang Province ranks at the forefront among the 31 provinces in China [37][38]. However, it is evident that many TCM hospitals in Zhejiang Province still need to enhance their health resource allocation efficiency. This study suggests that these TCM hospitals can undertake measures to improve key indicators such as total income, number of diagnosed and treated patients, and number of discharged patients, in order to enhance the overall efficiency of health resource allocation by optimizing the input-output relationship. In the complex situation of low management efficiency, redundant and insufficient investment [39], government departments should carefully consider the efficiency of resource allocation in reality, and allocate high-quality TCM resources reasonably according to needs. When providing health financial funding to TCM hospitals in each county, the focus of investment will be adjusted to improve efficiency, to avoid blind expansion and redundancy of health resource investment scale [40].

4.2. Spatial auto-correlation and agglomeration

In 2021, the average Moran's index of 71 county-level hospitals in Zhejiang Province was positive (0.131) and passed the 1% significance level test. This indicates that the efficiency of health resource allocation in most county-level hospitals in Zhejiang Province exhibits significant auto-correlation in spatial distribution.The efficiency value regression results also confirm this conclusion. Additionally, the study illustrated the specific spatial correlation situation in these county-level hospitals by utilizing the Moran scatter diagram and the cluster test table. The results revealed that 60.56% of hospital efficiency points are situated in spatial agglomeration quadrants, while only 39.44% are located in spatial discretization quadrants. There are distinct differences in the spatial agglomeration and discretization of various hospitals. For instance, in the quadrants of spatial agglomeration, the efficiency values of Gongshu, Xiaoshan, and other regions fall within the first quadrant (high-high), indicating that the efficiency of TCM hospitals in these areas is high and surrounded by other counties with high efficiency; the efficiency values of Tonglu and Chun'an are in the third quadrant (low-low), signifying that the efficiency of TCM hospitals in these regions is low and surrounded by other counties with low efficiency. Conversely, in the spatially discretization quadrants, the efficiency values of Fuyang, Beilun and other regions are located in the second quadrant (low-high), indicating that the health resource allocation efficiency of TCM hospitals in these regions is low but surrounded by other counties with high efficiency; the efficiency values in Jindong and Yiwu regions are located in the fourth quadrant (high-low), highlighting the efficiency of health resource allocation of TCM hospitals in these regions as high but surrounded by other counties with low efficiency.

In order to promote the balanced development of the health undertaking in Zhejiang Province, measures such as strengthening communication between counties and establishing a comprehensive health service data management system can be implemented to form a wide-coverage network structure [41][42][43]. These measures can mitigate resource constraints between regions and establish a health resource cooperation mechanism with surrounding regions by leveraging the spillover effect of high-efficiency health resource allocation regions.

4.3. Output oriented efficiency improvement methods

This study finds that public fiscal expenditure exerts a significant negative impact on the resource allocation efficiency of regional TCM hospitals, revealing a structural tension between the scale of fiscal investment and the quality of resource allocation. Blindly injecting excessive funds into hospitals may induce resource redundancy and inefficient utilization, thereby undermining overall allocation efficiency [44]. The number of beds in pension service institutions demonstrates an inhibitory effect on local efficiency, yet its spatial lag term is significantly positive, indicating pronounced spatial externalities. Specifically, the expansion of local pension beds may intensify structural imbalances within the health service system due to competitive allocation of medical and care resources or functional overlap; conversely, the agglomeration of elderly care facilities in neighboring regions generates positive spillover effects on local TCM hospital efficiency through service externalities, functional complementarity, and the alleviation of aging-related pressures. Additionally, the number of sports venues is significantly negatively correlated with the resource allocation efficiency of TCM hospitals, a finding that may reflect structural imbalances in the allocation of regional public resources. Under constraints of limited fiscal or spatial resources, the prioritization of sports facility layout may be accompanied by relative underinvestment in TCM medical institutions or lead to medical resource scales exceeding actual service demands, thereby manifesting as suboptimal allocation efficiency.

To enhance health resource allocation efficiency, an urgent paradigm shift is required from scale-orientation to efficiency-orientation, with strengthened optimization and reorganization of existing resources; administrative barriers must be dismantled to facilitate functional synergy and information sharing between local pension institutions and neighboring medical facilities; and spatial planning of public resources must be optimized to achieve quality transformation, efficiency transformation, and dynamism transformation.

4.4. Limitations and Future Directions

First, theoretically speaking, the health undertaking exhibits the characteristics of multiple inputs and outputs coexisting with expected and unexpected outputs. Nonetheless, in this research, some unexpected outputs such as the medical expenses of outpatient and inpatient have not been put into the calculation of efficiency value, and some indicators that have been taken into account cannot comprehensively summarize the input and output situation of TCM hospitals in Zhejiang Province.Second, when using DEA to research efficiency, researchers often delve into further decomposing productivity to observe the specific causes of inefficiency, but only panel data can facilitate this decomposition [45]. As for this study, only single cross-sectional data from Zhejiang Province in 2021 was collected, thus preventing the decomposition and analysis of the efficiency of health resource allocation productivity.

To address this limitation, future research must prioritize the systematic collection of longitudinal panel data spanning multiple years. By doing so, subsequent studies can employ dynamic evaluation methods, such as the Malmquist productivity index, to track efficiency trends over time, decompose productivity changes into technological progress and efficiency changes, and thoroughly map the spatiotemporal evolution of resource allocation in TCM hospitals.

5. Conclusion

This research utilized health resource data from county-level TCM hospitals in Zhejiang Province in 2021 to assess the efficacy of health resource allocation using the super-efficiency SBM model. The findings revealed that the overall efficiency of health resource allocation in county-level TCM hospitals in Zhejiang Province was relatively low and exhibited significant disparities across different counties. Moreover, the study employed Moran's Index to demonstrate spatial auto-correlation in the efficiency of health resource allocation in these hospitals. By constructing spatial econometric models based on inverse distance square matrix, the factors such as general public budget expenditures, number of beds in pension service institutions, and number of sports venues were identified as the factors that can significantly affect the efficiency of health resource allocation. Therefore, improving the efficiency of health resource allocation in Zhejiang Province requires leveraging the spillover effect from regions with high efficiency, prudent control of total general public budget expenditures, and attention to the number of beds in pension service institutions and sports venues. These approaches aim to promote nationwide sports and health, align investment in health resources with actual service needs, and effectively enhance the efficiency of health resource allocation ultimately.

A.1. Abbreviations

AIC: Akaike Information Criterion
BIC: Bayesian Information Criterion
DMU: Decision Making Unit
DEA: Data Envelopment Analysis
PGDP: Per capita Gross Domestic Product
HECP: Healthy Environments and Communities Program
OECD: Organization for Economic Co-operation and Development
OLS: Ordinary Least Squares
SAR: Spatial Auto Regression
SBM: Slack Based Measure
SDM: Spatial Dubin Model
SEM: Spatial Error Model
TCM: Traditional Chinese Medicine
W: The rook geographical adjacency spatial weight matrix.
WHO: World Health Organization

A.2. Author contributions

LH is the sole author of this manuscript and is responsible for all aspects of the study, including conception and design, data collection and analysis, interpretation of results, drafting and revising the manuscript, and approval of the final version for submission.

A.3. Availability of data and materials

The generated datasets for this study can be found in the China Statistical Yearbook Website https://tjj.zj.gov.cn/col/col1525563/index.html.

A.4. Competing interests

The author declares no conflicts of interest.

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