

Evaluation of the Coordinated Development of China's Health Resources and Regional Economy

Qiang Fengjiao, Xu Yuxuan*, Luo Wenchun

School of Economics and Management, Shaanxi University of Science & Technology, Xi'an, 710021, China

*Corresponding author: sxxaxyx@126.com

Abstract: The coupling coordination degree of health resources and regional economy in 31 provinces from 2011-2021 was calculated by using coupling coordination degree model, Thayer decomposition and other methods, and then its spatio-temporal evolution characteristics were evaluated. The results showed that: (1) the coupling coordination degree of health resources and regional economy in China showed an upward trend during the sample period. (2) The regional differences in the coordinated development of health resources and regional economy are significantly greater than those between regions, and the differences within the eastern region are showing an expanding trend. (3) Beijing, Tianjin, and the Jiangsu Zhejiang Shanghai region have been at a high level of coordination for a long time, while the process of health and economic coordination in non coastal provinces in the Southwest, East China, and North China is relatively slow. Therefore, the coordinated development of health economy can be promoted by optimizing the allocation of health resources and integrating into the overall situation of the "the Belt and Road" construction according to local conditions.

Keywords: Health resources; Regional economy; coupling coordination degree; Spatiotemporal evolution

1. Introduction

Health resources are essential elements for ensuring the physical health of the people [1]. The physical health of the people is the fundamental condition for promoting economic development [2], and economic development can provide guarantees for the rational allocation of health resources [3]. In recent years, the spatial differentiation distribution trend of China's health resources has been significant [4], and the uneven state of regional economic development has improved [5]. The balanced development trend of regional economy has also significantly reduced the differences in the allocation of health resources [6]. However, due to the comprehensive impact of the current health resource base, regional industrial structure, and global public health governance, there is still a lack of accurate evaluation and unified planning in the coordination of health resources and regional economy in various regions, resulting in unclear measures for the coordinated development of the two systems. On the one hand, the issue of per capita scarcity of health resources in some economically developed provinces is becoming increasingly prominent, mainly due to the limited and lagging investment channels and increments of health resources. For example, human resources and technological factors have specific training cycles, which prevent the total amount of health resources from continuously increasing with economic development. On the other hand, some economically underdeveloped provinces are prone to situations where local finance is insufficient to support existing health resources. This is mainly because measures such as public health services for all and optimization of rural health systems have accelerated the equalization of medical and health services, resulting in their health resource allocation exceeding the level of economic development. Therefore, this paper will analyze the coordination degree and spatiotemporal evolution pattern of health resources and regional economy in various provinces of China, in order to further promote high-quality development of the health economy.

2. Research methods

2.1 Coupled co scheduling model

Introduce a coupling coordination model to calculate the interrelationships between health resources

and regional economic systems, and evaluate their dynamic evolution process. The specific steps are as follows:

(1) By improving the entropy method model, the comprehensive scores of health resources and regional economy for each province in each year were obtained, represented by U_1 and U_2 respectively.

(2) Calculate the coupling between two systems:

$$C = \frac{\omega\sqrt{U_1 \times U_2}}{U_1 + U_2} \quad (1)$$

In equation (1), ω is the adjustment coefficient, which is taken as 2 in this paper; C represents the coupling degree of two subsystems.

(3) Calculate the comprehensive coordination index:

$$T = \alpha U_1 + \beta U_2 \quad (2)$$

In equation (2), T is a comprehensive evaluation index that reflects the overall synergistic effect of the two subsystems. α is the contribution coefficient of health resources, β is the contribution coefficient of regional economy, and $\alpha + \beta = 1$. Here, it is considered that the two subsystems are of the same level, so the value $\alpha = \beta = 0.5$ is assigned.

(4) Calculate the coupling co scheduling between two systems:

$$D = \sqrt{C \times T} \quad (3)$$

2.2 Analysis of spatial hotspots

Introducing hotspot analysis (Getis Ord) to identify the local autocorrelation relationship of health economy coordination, the mathematical formula is as follows:

$$G_i = \frac{\sum_{j=1}^q (w_{ij} \times D_j) - \bar{D} \sum_{j=1}^q w_{ij}}{S \sqrt{\frac{q \sum_{j=1}^q (w_{ij})^2 - (\sum_{j=1}^q w_{ij})^2}{q-1}}} \quad (4)$$

In equation (4), D_j is the coupled co scheduling of province j; w_{ij} represents the spatial weight between provinces i and j (adjacent is 1, non adjacent is 0); \bar{D} is the average coupling coordination degree of all provinces in that year, S is the standard deviation, and the statistical result of G_i is the z-score.

2.3 Taylor decomposition

Using the Theil index to calculate the spatial differences in the coupling and coordination level of China's health resources and regional economic development, and further decomposing the overall Theil index into intra regional and inter regional differences to achieve effective analysis of the structure and sources of differences. The specific decomposition method is as follows:

$$Theil = Theil_w + Theil_B = \sum_{k=1}^K \left(\frac{I_k}{I} \times \ln \left(\frac{I_k/I}{P_k/P} \right) \right) + \sum_{k=1}^K \left(\frac{I_k}{I} \times \sum_{i \in k} \left(\frac{I_i}{I_k} \times \ln \left(\frac{I_i/I_k}{P_i/P_k} \right) \right) \right) \quad (5)$$

In equation (5), $Theil_w$ represents the intra regional Theil index, and $Theil_B$ represents the inter regional Theil index; I_k/I represents the Tyle index and its proportion to the total Tyle index of all provinces in the region k, while I_i/I_k represents the proportion of the Tyle index of coupling coordination degree in province i to the total Tyle index of all provinces in the region k; P_i/P_k represents the proportion of province i to the number of provinces in region k, while P_k/P represents the proportion of provinces in region k to the total number of provinces in the country.

3. Construction of evaluation index system and data sources

3.1 Construction of evaluation index system

Based on the connotation of health economics [7], the actual situation of mismatch between economic development and health resources [8], and the issue of unequal allocation of health resources caused by regional economic imbalance drawing on the research of scholars such as Li Liqing and Han Xinwei [9-10], Based on the requirements of the "14th Five Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of the Long Range Goals for 2035" regarding "optimizing regional economic layout, promoting coordinated regional development" and "comprehensively promoting the construction of a healthy China", this article constructs a coupling and coordination evaluation system for health resources and regional economy (Table 1). As shown in Table 1, the health and economic coupling coordination evaluation system covers two aspects: Health resources and economic development. (1) Health resource system: having a reasonable number of health facilities in the region is a fundamental guarantee for resource allocation and patient transport efficiency, so the number of medical institutions and the number of beds in medical institutions are selected as the health facility dimension indicators; Human resources are the first resource to ensure the normal operation of society, especially for highly professional and technical health systems. Here, licensed physicians and registered nurses who directly engage in clinical work will be used as dimensional indicators for health personnel [11]; Optimizing the structure of health expenditure is a livelihood measure that is related to the well-being of the people. Obviously, reducing the proportion of individual payments is imperative [12]. Government health expenditure urgently needs to play an important role in the coordinated improvement of health performance between urban and rural areas and regions. Social health expenditure will gradually become the pillar of health expenditure in the future. Therefore, the dimension of health expenditure should also pay attention to government health expenditure Two important indicators of social health expenditure. (2) Regional economic system: Per capita GDP can objectively reflect the level of social development in a certain region, and local finance is a necessary means to achieve income redistribution. The interaction and upgrading of the two will effectively empower industrial structure adjustment and further strengthen the foundation of the regional economy. Therefore, per capita GDP and per capita regional financial income are used as indicators of economic strength dimension; Research has shown that the tertiary industry has a significant positive effect in promoting the rationalization of employment structure [13], promoting economic growth and promoting industrial clusters, and increasing the proportion of the tertiary industry is in line with the current direction of industrial structure adjustment. Therefore, the proportion of the tertiary industry to GDP is used to measure economic structure; In addition, economic vitality and economic openness are also common practices for many scholars to evaluate the quality and sustainability of development. Based on the principle of data availability, this article selects two indicators: per capita retail sales of consumer goods and per capita total import and export volume.

Table 1: Evaluation Index System of Health Resources and Regional Economic System

Target layer	Criterion layer	Domain layer	Indicator layer
Health Resources and Regional Economic System	Health resources	Health facility	Number of medical institutions per 10000 people
			Number of beds per thousand people in medical institutions
		Health personnel	Number of practicing physicians per thousand people
			Number of registered nurses per thousand people
		Health expenses	Government health expenditure per thousand people
			Social health expenditure per thousand people
	Economic development	Economic strength	Per Capita GDP
			Per capita regional fiscal revenue
		Economic structure	The proportion of the tertiary industry to GDP
		Economic vitality	Per capita retail sales of social consumer goods
Economic Openness	Per capita total import and export volume		

3.2 Data sources

The indicators in this paper cover the data from 2011-2021, of which the health resource system indicators and total population are from the China Health Statistics Yearbook of the corresponding year, and the regional economic system indicators are from the China Statistics Yearbook of the corresponding year. In addition, the data on government health expenditure and social health expenditure in the Tibet Autonomous Region in 2011 were missing, and trend extrapolation was used to supplement them; The data on government health expenditure and social health expenditure in various provinces in 2021 is missing, and the grey prediction model GM (1,1) is used to supplement it.

4. Analysis of the Coordinated Evolution and Regional Differences of China's Health Economy

4.1 The overall trend of the coupling and coordination of China's health economy

In order to grasp the coordinated development trend of China's health economy, based on the calculation results of the coupling coordination degree between health resources and regional economy, a kernel density curve is drawn to reflect the overall characteristics of coordinated development, as shown in Figure 1.

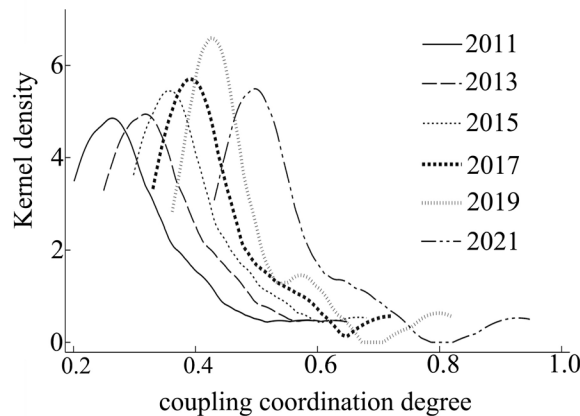


Figure 1: Kernel density analysis of health economy coupling coordination

From the perspective of shape, the nuclear density curve of coupled and coordinated development from 2011 to 2015 is relatively smooth, and the curve basically continues to decline after the peak; The nuclear density curve from 2017 to 2021 is relatively complex, with a slight upward trend occurring again after the peak, indicating significant spatial differences in the coordinated development of China's health resources and regional economy, which continue to evolve over time. From the perspective of location, the nuclear density curve of the coordinated development of China's health resources and regional economy is clearly shifting to the right, indicating that the overall coordination level of China's health economy is constantly rising. From the perspective of kurtosis, the nuclear density curve from 2011 to 2019 became increasingly steep, with a significant increase in peak height and a decrease in opening width, indicating a decrease in the differences in health and economic coupling coordination among provinces; From 2019 to 2021, the peak height decreased and the opening width increased, indicating that the differences in coordination levels among different provinces have expanded during this period.

4.2 Regional Differences in the Coordinated Development of China's Health Economy

To further investigate the provincial equilibrium state of coordinated development between China's health resources and regional economy, the overall Theil index trend of the coupling coordination degree between the two is depicted in the form of dots and lines, as shown in Figure 2.

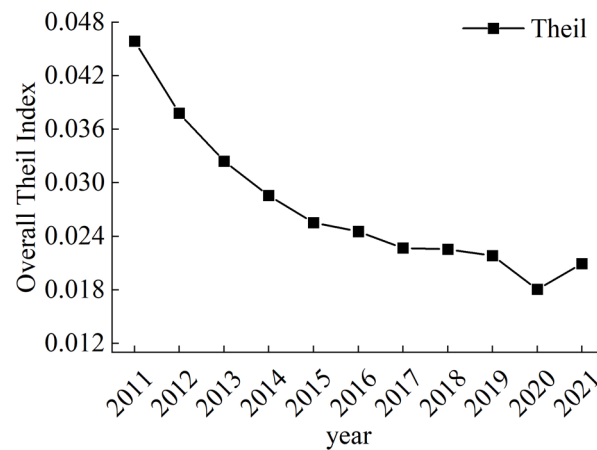


Figure 2: Overall Theil Index Change Trend of the Coupling and Coordination Degree between China's Health Resources and Regional Economy

The results in Figure 1 show that the overall difference between the coordinated development of China's health resources and regional economy shows a downward trend from 2011-2021, and has dropped to 0.021 by 2021, which indicates that the difference in the coordinated development of provinces is gradually narrowing. Therefore, it is necessary to accurately measure the differences between regions and between regions, and explore their proportion in the overall Theil index, so as to provide a clear direction for the coordination and optimization of the health economy. According to the standards of eastern, central, and western regions, China is divided into three regions, and the overall Theil index is further decomposed and discussed. The decomposition results are shown in Table 2.

Table 2: Decomposition results of Theil index contribution rate of China's health resources and regional economy coupling and coordination in 2011-2021

year	In region/%			Total within the region/%	Inter regional %
	Eastern Region	Central Region	Western Region		
2011	38.73	6.54	4.89	50.16	49.84
2012	40.89	5.50	5.44	51.84	48.16
2013	42.10	5.08	5.60	52.79	47.21
2014	43.73	4.50	6.44	54.68	45.32
2015	46.19	4.11	5.57	55.86	44.14
2016	47.79	4.10	4.62	56.50	43.50
2017	48.82	3.36	4.59	56.77	43.23
2018	49.81	2.68	4.56	57.05	42.95
2019	53.59	2.95	3.61	60.16	39.84
2020	56.19	2.29	3.51	61.99	38.01
2021	54.30	1.46	4.14	59.90	40.10

As shown in Table 2, the proportion of differences in the eastern region has expanded, while the differences in the central and western regions have shown a decreasing trend. Specifically, the proportion of differences among the eastern provinces in the overall difference fluctuated between 38.73% and 56.19%, but remained higher than that of the central and western regions. The Theil index contribution rate of the coupling coordination degree in the central region has been relatively low for a long time and has shown a significant downward trend, indicating that the differences between the provinces in the central region are relatively small and constantly tending towards balanced development. The Theil index of the coupling coordination degree of health and economic development in the western region shows a basic pattern of first increasing and then decreasing, indicating that the balanced development of health resources and regional economy in the region has also improved in recent years.

At the same time, the difference in the coordination degree of health economy coupling among the three major regions has significantly narrowed. In 2011-2021, the contribution rate of Theil among regions decreased from 49.84% to 40.10%. Obviously, the inter provincial differences in health and economic coordination within the eastern region have become the main factor in imbalanced development.

4.3 Analysis of the Provincial Temporal and Spatial Evolution of the Coupled and Coordinated Development of China's Health Economy

According to the measurement values of coordinated development of health economy in each period, the coupling coordination degree is classified into: severe imbalance area, mild imbalance area, general coordination area, good coordination area, and high-quality coordination area; The higher the value, the higher the level of coupling and coordination between health resources and regional economy in the region.

The research results show that the spatial distribution of the coupling and coordination between China's health resources and economic development has undergone significant changes. (1) From 2011 to 2016, many provinces along the eastern coast and Inner Mongolia in the northern border, as well as Chongqing and Hubei in the inland hinterland, took the lead in achieving further coupled development, breaking the original state of mild imbalance between health resources and regional economy in most regions of China. (2) From 2016 to 2021, the coupling and coordination degree of health economy in various provinces across the country has generally improved; The Yangtze River Delta and Pearl River Delta regions have once again achieved advanced development, second only to Beijing and Shanghai, both at a relatively high level in China. At this point, there are no dysfunctional areas nationwide, but most areas are only at a general level of coordination. In general, health resources and regional economic development in 2011-2021 have changed significantly in different periods but have their own characteristics. The coordinated development of eastern coastal provinces is fast and at a high level.

To clarify the spatial evolution trajectory of coordinated development of the health economy, this article introduces the spatial autocorrelation method to further explore its spatial differentiation characteristics. The Moran's I is used to determine the global autocorrelation characteristics for 2011, 2016, and 2021. The results are shown in Table 3.

Table 3: Global autocorrelation Moran's I index and test values

	2011	2016	2021
Moran's I	0.364	0.332	0.334
Z-value	3.511	3.245	3.390
P-value	0.000	0.001	0.001

From Moran's I (Table 3), the global Moran index for the coordinated development of China's health resources and regional economy in 2011, 2016, and 2021 were all greater than zero, and can be tested for significance, indicating a significant spatial correlation, with a consistently high degree of spatial agglomeration. In order to more clearly demonstrate the distribution and aggregation of coordinated development between health resources and regional economy in the local province, this article identifies the local autocorrelation relationship through hotspot analysis, and the results are shown in Table 4.

Table 4: Analysis of Hot Spots for Coupled and Coordinated Development of Health Economy

	Hot spot area			Cold spot area		
	99% confidence interval	95% confidence interval	90% confidence interval	99% confidence interval	95% confidence interval	90% confidence interval
2011	—	Shanxi, Henan, Shandong	Beijing, Tianjin, Hebei, Shanghai	—	Chongqing	Guangdong, Hainan
2016	Henan	Shanxi, Shandong	Beijing, Tianjin, Hebei, Shanghai	—	—	Hainan
2021	Henan	Shanxi	Shaanxi, Shandong, Shanghai	—	—	—

In Table 4, the spatial clustering patterns of high and low value areas under different confidence levels are shown: (1) In 2011, at a 95% confidence level, Shanxi, Henan, and Shandong belong to hot spot areas, while Chongqing belongs to cold spot areas; At a 90% confidence level, the Beijing Tianjin Hebei region can be added as a hot spot area, further forming a concentrated and contiguous hot spot distribution with the original three provinces. At the same time, two cold spot provinces have emerged, namely Guangdong and Hainan across the Qiongzhou Strait. (2) From 2011 to 2016, Henan became a hot spot

area at a 99% confidence level, with the only remaining cold spot area being Chongqing at a 90% confidence level. (3) From 2016 to 2021, Shaanxi was newly added as a hot province at a 90% confidence level, while Shandong was downgraded to a hot province at a 90% confidence level. The Beijing Tianjin Hebei region is no longer a hot area. In general, the hot areas of the coupled and coordinated development of China's health resources and regional economy from 2011 to 2021 have a trend of shifting from coastal areas to inland areas, and gradually evolved into hot provinces with a higher confidence level, and the cold areas have gradually shrunk and dissolved; The above phenomena indicate that the provinces in China where health resources and regional economy are highly coupled and coordinated are no longer limited to coastal areas, and their spatial aggregation effect is becoming increasingly evident. With the long-term coordination of health resources and regional economy, there will be no significant cold spot areas in 2021.

The change of spatial autocorrelation in 2011-2021 can further reflect the spatial distribution characteristics of the coupling and coordinated development of health resources and regional economy in China's provinces. (1) The aggregation phenomenon of low and high values in the eastern region has weakened, and both hot and cold spots in the region are in a state of contraction. Obviously, the Beijing Tianjin Hebei region, Guangdong, and Hainan have evolved from hot and cold spots to insignificant regions, which is conducive to balanced development within the region. (2) Most provinces in the central region have always belonged to insignificant regions and have not been identified by hot spot analysis methods. However, Henan and Shanxi provinces have long been hot spots and have always had a diffusion effect on surrounding provinces. Moreover, the significance level of Henan province as a hot spot province has also increased, and it has become the radiation core of national hot spots. (3) In the coordinated development of the western region, the phenomenon of low value clustering in the southwestern mountainous areas has been overcome. Shaanxi Province, located in the northwest inland hinterland, has gradually become a patchy hot spot area with neighboring central and eastern provinces. This indicates that there is no concentrated low-level coupling coordination area in the western region, and there has been a distribution of high value areas, improving the overall coupling coordination level. Based on the above analysis, combined with the spatial spillover effects of health resources and economic development, it can be confirmed that the high value areas where health resources are coupled and coordinated with regional economy play a driving role in neighboring regions; For example, in 2016, Shaanxi was not a hot area, but its neighboring Henan and Shanxi provinces have always been hot areas, ultimately driving Shaanxi to become a hot area in 2021. Therefore, measures to improve the coupling and coordination level of health resources and regional economy in a certain region should not be limited to the region itself; If we can simultaneously consider the related development with surrounding areas, it will provide a more comprehensive reference for the overall coordination of the health economy.

5. Conclusion and Suggestions

This paper uses entropy method, coupling coordination degree model, nuclear density estimation, Theil decomposition and other methods to calculate and describe the coupling pattern of China's health resources and regional economy in 2011-2021, analyze its spatio-temporal evolution law, and draw the following conclusions: (1) From the perspective of the coordinated development degree of health economy, the coupling coordination degree of different regions increased differently in 2011-2021, but on the whole, it shows a remarkable trend of sustainable and good development. (2) From the perspective of regional differences in the coordinated development of health economy, the intra regional differences in 2011-2021 were significantly greater than the inter regional differences; The biggest difference within the eastern region has become an absolute key factor affecting overall differences. (3) From the perspective of the spatiotemporal differentiation characteristics of coordinated development of the health economy, in terms of spatial differentiation, in 2021, Jiangsu, Zhejiang, Shanghai, Fujian, Guangdong, Beijing, and Tianjin were all at a high level of coordination in the domestic health economy, while other regions were only at a general level of coordination. In terms of growth evolution, the coordinated development process of the eastern coastal areas is relatively fast, while the process of most inland provinces getting rid of imbalanced development is relatively slow. In 2011-2021, the hot areas of health and economy coupling and coordination have a trend of shifting from coastal areas to inland areas, gradually evolving into hot provinces with a higher confidence level, and the cold spot areas gradually shrink. In 2021, there will be no cold spot areas nationwide.

Based on the above conclusions, in order to further improve the coupling and coordination of China's health resources and regional economy, narrow regional differences, and achieve high-quality development, the following suggestions are proposed: (1) Optimize the allocation pattern of health

resources. On the one hand, we need to break regional restrictions and jointly build national and regional medical centers to ensure that high-quality medical resources benefit more people; On the other hand, it is also necessary to make up for the relative shortcomings in the allocation of local health resources and promote the flow of resources from the east to the central and western regions. (2) Actively identify the development track of regional economy and actively integrate into the overall situation of the "the Belt and Road" construction. (3) Adhere to the concept of coordinated development and guide the mutual promotion of health resources and regional economy. On the basis of fully understanding the coordinated development law of China's health resources and regional economy, consider the health economy composite system with a holistic and systematic approach, identify the main reasons for the disharmony of health economy in different regions, and determine the development direction in an orderly manner.

Acknowledgements

Annual Project of Shaanxi Provincial Social Science Foundation (2022D034); Shaanxi Province Philosophy and Social Science Research Special Youth Project: (2023QN140).

References

- [1] Yang Yingce, Yu Jiali, Xia Mengfan. *Research on the Coordination between Residents' Health Level and Medical and Health Resource Investment [J]. Statistics and Decision Making*, 2021, 37 (11): 53-57.
- [2] Shan Jingjing. *Building a Healthy China: Current Situation, Problems, and Countermeasures [J]. Zhongzhou Academic Journal*, 2018 (02): 71-77.
- [3] Chen Minhui, Xu Wenjing. *Empirical analysis of unequal allocation of health resources caused by regional economic development imbalance [J]. China Health Statistics*, 2018, 35 (01): 55-57.
- [4] Dong Enhong, Yan Yue, Xie Yali, Wang Yijia, Wang Tao, Chen Cheng, Dong Siping. *Research on the Degree of Regional Differentiation and Spatial Distribution Trends of Health Resource Allocation in China (2009-2020) [J]. China Health Policy Research*, 2022, 15 (06): 73-79.
- [5] Lv Chengchao, Suo Qi, Yang Huan. *Is there a significant economic gap between the "North South" or "East West" regions—Comparative Study on Regional Economic Disparities and Their Influencing Factors in China [J]. Quantitative Economic and Technological Economic Research*, 2021, 38 (09): 80-97.
- [6] Jin Shuting, Li Bo, Yang Yongchun. *Does economic development narrow the gap in the supply of basic medical and health resources among regions—Econometric testing based on panel data from 287 cities [J]. World Geographic Research*, 2021, 30 (01): 192-203.
- [7] Coast J, Smith R D, Lorgelly P. *Welfarism, extra-welfarism and capability: The spread of ideas in health economics [J]. Social Science & Medicine*, 2008, 67(7):1190-1198.
- [8] Han Yue. *The relationship between economic development and healthcare development in various regions of China [J]. China Health Statistics*, 2018, 35 (04): 603-604.
- [9] Li Liqing, Zhou Xu, Zhao Yulan, Lu Zuxun. *A study on the coupling and coordination relationship between grassroots medical resource allocation and economic development in the eastern, central, and western regions of China [J]. Chinese Journal of General Medicine*, 2021, 24 (22): 2777-2784.
- [10] Han Xinwei, Ma Di, Chen Miaomiao, Li Binghang, Liu Jinmei, Du Jin, Ma Anning, Wang Chunping, Ma Guifeng, Cai Weiqin, Gao Qianqian. *A study on the coupling and coordination of medical service capacity and regional economy in 31 provinces of China [J]. Medicine and Society*, 2022, 35 (08): 39-43+48.
- [11] Gong Hanxiang, Wu Zeyong, Wu Baoling, Ye Qiuli, Luo Zhenni. *Evaluation and Analysis of the Spatial Agglomeration Characteristics of Medical and Health Resources in Guangdong Province [J]. China Health Economy*, 2017, 36 (05): 52-55.
- [12] Dong Liming, Yao Qiaoyan. *Research on Improving the Financing Mechanism of Basic Medical and Health Services in China [J]. Price Theory and Practice*, 2009 (04): 43-44
- [13] Mao Rui, Xu Jianwei. *Adjustment of Labor Force Structure and Industrial Structure [J]. Journal of Zhejiang University (Humanities and Social Sciences Edition)*, 2015, 45 (02): 164-183.