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Study on the Fairness Measurement of Regional Innovation Resource Allocation and Its Spatial Correlation Features

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Abstract:

The imbalance of China' s economic and social development leads to significant unfairness in the regional innovation resource allocation, which not only leads to excessive innovation polarization and insufficient diffusion in the first developing areas, but also seriously inhibits the late developing advantage potential of the late developing areas. The improved weighted relative Theil index and social network analysis are used in this paper to explore the fairness of innovation resource allocation and its spatial correlation features in China' s eight economic zones from 2011 to 2019. The results show that: (1) There are significant differences in the fairness of regional innovation resource allocation, and obvious ladder levels are existed. (2) The fairness of regional innovation resource allocation continues to improve, which reflects the advantages of regional linkage development. (3) The differences in the regional innovation resource allocation are mainly reflected in the inter-regional differences, and the difference contribution rate of inter-regional differences to the overall differences is continually greater than that of intra-regional differences to the overall differences during the study period. (4) The relative network of the fairness of regional innovation resource allocation has a certain foundation, but its resilience and stability are weak. (5) The fairness of regional innovation resource allocation has a large hierarchical ladder, and the differences are significant.

Keywords*: Regional innovation resource allocation, Fairness, Weighted relative Theil index, Spatial correlation.*

I. INTRODUCTION

With the improvement of China' s support for scientific and technological innovation, the innovative industry is making a spurt of progress, and the output of innovation achievements is increasing significantly. Innovation has become the "first driving force" to lead the development, and innovative resources, as the "first resource", constantly promote scientific and technological progress and social development. However, at present, there is a significant Unfairness in the allocation of regional innovation resources, and the differences in innovation capabilities among regions continue to expand, which has

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become the main bottleneck of regional coordinated development. General Secretary Xi Jinping clearly pointed out in the report of the 19th National Congress of the Communist Party of China that based on promoting development continuously, we should focus on solving the problem of insufficient development imbalance and vigorously improve the quality and efficiency of development [1]. In that case, what is the unfair allocation of innovation resources in Chinese mainland like? What are the differences in the unfair situation in different regions? What are the related characteristics of the fairness of innovation resource allocation in different regions? In-depth study of the above problems is helpful to correctly understand the unbalanced fact of regional innovation resource allocation in China, and then provide reference for scientifically formulating relevant policies and plans for regional innovation development.

The related study results of the fairness of innovation resource allocation are mainly divided into two categories: the first category focuses on the difference analysis of innovation efficiency, mainly studying the regional differences in innovation efficiency [2-8], innovation ability [9-12] and innovation benefit [10-17]. Zhang Huiqin et al. [13] analyzed the current situation of innovation knowledge output from the geographical pattern. The results show that there is an imbalance in China' s innovation in geography and industry; Ni Qingshan et al. [17] explored the differences and changing trends of urban innovation performance in China, and found that there are great differences in urban innovation performance and there exists obvious imbalance in distribution; Li Xiang [18]chose the Yangtze River Economic Belt as the research object to analyze the spatial imbalance of innovation-driven integrated development; Ma Ru and Wang Hongwei[15] selected several key urban agglomerations, made a comparative analysis of the unbalanced characteristics of innovation activities, and found that the gap in talents and economy between central cities and surrounding cities caused the polarization of regional innovation output. The second type of study focuses on the analysis of influencing factors of the difference of innovation efficacy [20-27]. For example, Wang Xuehong[20] believes that there are obvious regional differences in the scale of innovation resources, and the results show that the main factor for this difference is the investment scale of innovation resources; Yang Qian et al. [21] believe that the transaction volume of technology market and the weighted number of three domestic patents play a more important role in the regional differences of scientific and technological innovation efficiency in major national strategic regions, so enhance the equilibrium degree of the weighted number of three domestic patents and the transaction amount of technology market is helpful to reduce the regional differences in the efficiency of scientific and technological innovation in major national strategic regions.

Viewed from the existing research, at present, there are some problems including prominent difference in innovation ability and obvious gap in innovation level in China's regional innovation development. However, what are the specific performances of the differences in the innovation resource allocation in each region? What are the performances of relative features of the fairness of innovation resource allocation in each region? The relevant study is rarely involved at present. In view of this, this study used the panel data of 31 provinces and cities and eight economic zones in Chinese mainland from 2011 to 2019 as samples, used the improved weighted relative Theil index to measure the fairness and temporal spatial evolution of innovation resource allocation in each region, and used social network analysis to deeply explore its spatial association characteristics, in order to provide theoretical basis and realistic basis for

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promoting coordinated development of regional innovation.

The fairness of innovation resource allocation refers to the balance of innovation resources such as human, financial, material resources in each region, and the matching with the total population and economic foundation of each region. In particular, it should be pointed out that the fairness of the innovation resource allocation studied in this paper is not an absolute fairness of the distribution of innovation resources in each region, but a relative fairness matching and corresponding to the total population and economic foundation of each region. Because the conditions of productivity development in each region are different, there are also differences in the demand for innovation resources. Emphasizing fairness is not the pursuit of absolute equalitarianism, but the pursuit of the matching ability and coincidence between the number of regional innovation resource allocation and the basis of regional development, in order to realize the balance of innovation resource allocation in each region.

II. STUDY METHODS AND DATA SOURCES

2.1 Study Methods

2.1.1 Fairness Measurement of Regional Innovation Resource Allocation Based on Weighted Relative Theil Index

Theil index is a classical method used by academic circles to investigate fairness and disequilibria. It is a difference measure method creatively obtained by Theil from the concept of entropy. It has a good difference interpretation property, which can decompose the total difference and calculate the contribution degree of different differences to find out the specific existence form of differences. See detailed formula (1) for the calculation formula of Theil index. In order to clearly reveal the fair situation of regional innovation resource allocation, based on the regional division method in the report "Strategy and Policy of Regional Coordinated Development" issued by the Development Research Center of the State Council, which divids Chinese mainland into eight comprehensive economic zones, namely Northern Coastal Comprehensive Economic Zone (North Coast): Beijing, Tianjin, Hebei and Shandong; Eastern coastal comprehensive economic zones (East Coast): Shanghai, Jiangsu and Zhejiang; Southern coastal comprehensive economic zones (South Coast): Fujian, Guangdong and Hainan; Northeast Comprehensive Economic Zone (Northeast): Liaoning, Jilin and Heilongjiang; Comprehensive Economic Zone in the Middle Reaches of the Yellow River (Middle Yellow): Shaanxi, Shanxi, Henan and Inner Mongolia; Comprehensive economic zones in the middle reaches of the Yangtze River (Middle Yangtze): Hubei, Hunan, Jiangxi and Anhui; Southwest Comprehensive Economic Zone (Southwest): Yunnan, Guizhou, Sichuan, Chongqing and Guangxi; Northwest Comprehensive Economic Zone (Northwest): Gansu, Qinghai, Ningxia, Tibet and Xinjiang.

$$T = \frac{1}{I}\sum_{i=1}^{I} w_i \frac{X_i}{\overline{X}} \ln[\frac{X_i}{\overline{X}}] \quad (1)$$

where: T is the Theil index, which is used in this paper to measure the fairness of regional innovation resource allocation; I is the number of research samples, and this paper use it to indicate the number of

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provinces and cities included in the overall or region; X represents the total allocation of innovative resources, and X_i is refers to the sample data of the same indicator in different regions the variable X; when the value of T is 0, it means that there is no difference at all between all samples; otherwise, if the value of T is a positive number, and the higher the value is, the greater the difference between sample individuals exist and the weaker the fairness is.

Because the traditional Theil index relies too much on the absoluteness of a single variable, it is easy to ignore the differences between different provinces and cities due to their economic development level or population, which can be referring to relevant literature[27]. Under this circumstance, this paper adopts the improved weighted relative Theil index to measure the fair situation of regional innovation resource allocation,

$$T = \sum_{i=1}^{I} w_i \frac{\frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \ln[\frac{\frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}}] \quad (2)$$

where $\Pi_i$and $w_i(\sum_i w_i = 1)$ are the reference benchmark and assigned weight of the *i*-th sample on the research variable *X*, respectively. The reference benchmark for innovation human input in this paper is the total population at the end of each observation year of each province, city and economic zone, and the reference benchmark for innovation financial investment and material investment is the total GDP of each province, city and economic zone in each observation year; this paper w_i selects proportion of the year-end total population of each region. When $\frac{X_i}{\Pi_i} = \frac{X_i}{\Pi_i} = \cdots = \frac{X_i}{\Pi_i}$, the value of T is 0; otherwise, T>0; when$\Pi_i = 1$ and $w_i = 1/I$, the traditional Theil index calculation formula is obtained, namely Formula 1). Comparing formulas (1) and (2), it can be seen that the weighted relative Theil index adds the concept of relative weight to the traditional Theil index, and converts the independent absolute sample values scattered in each area into a relative comparison under the same benchmark value, and more scientifically present the uneven degree of innovation resource allocation in fair spaces.

One of the advantages of using Theil exponent to measure fairness is that it takes advantage of its unique decomposable property. Generally speaking, after calculating the overall difference, it can be decomposed into intra-regional differences and inter-regional differences, and the eight economic zones can be decomposed twice to explore the sources of difference allocation of innovation resources in China at multiple levels. The improved Theil index decomposition formula is as follows:

$$T = T_w + T_b \quad (3)$$

$$T = \sum_{r=1}^{R} w_r \frac{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \sum_{i \in I_r} \frac{w_i}{w_r} \frac{\frac{X_i}{\Pi_i}}{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}} \times \ln\left[\frac{\frac{X_i}{\Pi_i}}{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}}\right] + \sum_{r=1}^{R} w_r \frac{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \times \ln[\frac{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}}] +$$

$$\sum_{r=1}^{R} w_r \frac{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \times \ln[\frac{\sum_{i \in I_r} \frac{w_i X_i}{w_r \Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}}] \quad (4)$$

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where T_w is the Theil index of intra-regional innovation resource allocation, T_b is the Theil index of inter-regional innovation resource allocation, and $R(r = 1, \ldots, R)$ indicates the number of regions, w_r is the weight of the rth region, $w_r = \sum_{r=1}^{R} w_r$.

2.1.2 Analysis of Spatial Correlation Features of Regional Innovation Resource Allocation Fairness Based on Social Network Analysis

(1) Improved gravity model

The theory of universal gravitation was introduced by Geographers and social scientists into the study of economic geography earlier and became an important cornerstone of the study of economic geography. The theory holds the point that between population, economic aggregate and spatial distance, there is a close relationship existing. And the connection strength between different geographical units can be measured by making use of this model. In order to reflect the correlation status of regional innovation resource allocation in a more accurate way, the modified gravity model is used to build a correlation network for China' s regional innovation resource allocation fairness. Geographical distance and economic distance are used at the same time to measure the distance between cities. The specific calculation formula is as follows:

$$RF_{ij} = kf_{ij} \frac{\sqrt[3]{P_i f_i G_i} \cdot \sqrt[3]{P_j f_j G_j}}{\frac{D_{ij}}{(PerG_i - PerG_j)^2}} \quad (5)$$

Where: $kf_{ij} = \frac{f_i}{f_i + f_j}$, RF_{ij}indicates the connection intensity of the allocation fairness between region i and region j, kf_{ij} is the influence intensity of the ith region on RF_{ij}, P_i and P_j respectively indicate the population of region i and region j, f_i and f_j are the measurement values of allocation fairness of region i and region j respectively, G_i and G_j respectively indicate the GDP level of region i and region j, D_{ij} indicate the spatial distance between region i and region j, and $PerG_i$ and $PerG_j$ indicate the per capita GDP level of region i and region j respectively.The geographical distance (D_{ij}) between region i and region j divided by the difference ($PerG_i - PerG_j$) of per capita GDP between region i and region j is a number, and the number is used to correct the "distance" between regions.

(2) Social network analysis

Social network analysis (SNA) takes the network composed of associated nodes as the study object. And in this analysis, the features of network structure, topology, node features and dynamic characteristics in the network are the emphases to pay attention to. SNA is widely used in financial system, power system, social system and other fields by using complex network theory. Economic geographers introduce the idea of network system analysis to connect the node cities in the urban agglomeration or economic belt through information, capital, materials, population, and other flow elements to construct the urban network. Through these works, the overall, local and individual features of the network can be analyzed.

On the basis of the connection strength of the fairness of innovation resource allocation among regions, the connection adjacency matrix A_{ij} of each region can be constructed; Then, the connection strength and

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threshold size between region i and region j can be compared respectively by taking the average $\overline{R_\tau}$ of each row of matrix A_{ij} as the threshold: if $R_{ij} > \overline{R_\tau}$, it is considered that there is a connection of allocation fairness between the two, otherwise, it is considered that there is no economic connection between region i and region j, and finally the economic association network in each region of the whole country can be obtained. The spatial correlation features of the fairness of innovation resource allocation in each region can be measured by making use of network density, average distance, average degree and other indicators.

2.2 Data source and processing

The study objects in this paper are the eight major economic zones of Chinese mainland including the northeast area, the northern coastal area, the eastern coastal area, the southern coastal area, the middle reaches of the Yellow River, the middle reaches of Yangtze River, the southwest area and the northwest area. There are 31 provinces and cities together, with a time span from 2011 to 2019. Comprehensively considering the scientificity of each evaluation index and the comparability of data, based on referring to relevant research, this paper selects the full-time equivalent of R&D personnel, the total number of scientific and technological activities to represent the innovative human resource allocation, selects R&D activity expenditure, new product development expenditure, technology acquisition and technological transformation expenditure to represent the allocation of innovative financial resources, and selects R&D instrument and equipment expenditure to represent the allocation of innovative material resources. The details can be seen in TABLE I. The data used in this paper are from the websites of governments in each province or each city, *China Statistical Yearbook, China Science and Technology Statistical Yearbook* and *Torch Statistical Yearbook.*

TABLE I Regional innovation resource allocation equity measurement index system

1- level index	2-level index	3-level index	Unit
Innovation resources allocation	Innovative human resource allocation	Full time equivalent of R & D personnel	Ten thousand people Year
		Total number of personnel engaged in scientific and technological activities	Ten thousand people
	Innovative financial resource allocation	R & D expenditure	Ten thousand Yuan
		New product development funds	Ten thousand Yuan
		Technology acquisition and technological transformation funds	Ten thousand Yuan

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	Innovative material resource allocation	R & D instrument and equipment expenditure	Ten thousand Yuan

III DISCUSSION ON EMPIRICAL RESULTS

3.1 Fairness Measurement of regional innovation resource allocation

Calculate the Theil index value of the fairness of innovation resource allocation in China and major economic zones from 2011 to 2019 by making use of Rstudio 4.0.4.Calculate the weight by the Fuzzy-AHP method on the basis of measuring the Theil index of each three-level index to obtain the Theil index of each two-level index of innovative human resource allocation, financial resource allocation and material resource allocation, and then the Theil index of total innovation resource allocation can be comprehensively obtained; then calculate the intra-regional and inter-regional Theil index of total innovation resource allocation by using formula (3) and formula (4), and analyze the difference contribution rate of intra-regional and inter-regional differences to the overall differences. At the same time, the measurement result data is used for drawing form in order to make the research results look more intuitive. The specific results can be seen in Fig 1, Fig 2, Fig 3 and Fig 4.

3.1.1 Fairness allocation of innovation resources in the whole region

(1) The fairness situation of innovative human resource allocation. It can be seen in figure 1 that the Theil index of innovative human resources showed a stable trend and increased slightly in general, and it increased by 2.93% during the study year, which indicates that there was little difference in the innovative human resource allocation in the whole country, and there was no significant improvement in the fairness situation of the innovative human resource allocation.

(2) The fairness situation of innovative financial resource allocation. It can be seen in figure 1 that, contrary to the fairness situation of the innovative human resource allocation, the Theil index of national innovative financial resources showed a significant downward trend, with its value falling from 0.063 in 20 11 to 0.039 in 2019. It is a decrease of 37.95%.And it is indicated that the difference in the investment of innovative financial resources among provinces and cities has been gradually decreased, and the fairness of the innovative financial resource allocation has been significantly improved.

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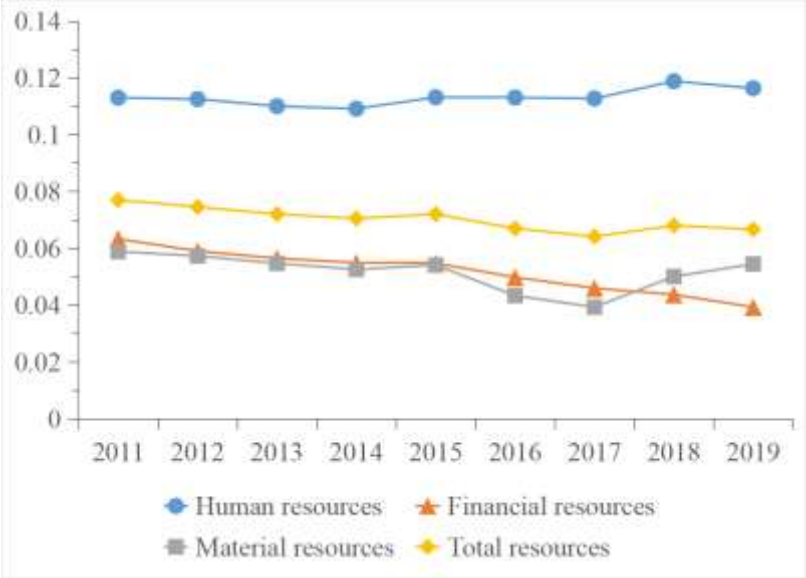

Fig 1: Trend chart of Theil index of national innovation resources from 2011 to 2019

(3) The fairness situation of innovative material resource allocation. It can be seen in Fig 1 that, the Theil index of innovative material resources is significantly lower than that of human resources and financial resources, and it shows a downward trend in general. It has rebounded slightly in the past two years, with the maximum value of 0.059 in 2011 and the minimum value of 0.039 in 2017, and its overall decline is 7.48% during the study year, which indicates that the difference in the innovative material resource allocation in the whole country is at a low level, the difference between provinces and cities is gradually decreasing, and the fairness of the national innovative material resource allocation has been significantly improved.

(4) The fairness situation of total innovation resource allocation. Overall, the Theil index of total innovation resources showed a steady downward trend from 0.077 in 2011 to 0.067 in 2019with a decrease of 13.43%.It is indicated that the disequilibrium of total innovation resource allocation in the whole country has decreased year by year and the fairness has been significantly improved.

3.1.2 Fairness situation of innovation resource allocation in the eight economic zones

(1) The fairness situation of regional innovation resource allocation. It can be seen in Fig 2 that, the inter-regional differences have an increasing trend in general. The inter-regional Theil index increased by 12.69% during the study year. In addition, compared with the intra-regional Theil index, it can be found that except 2011, the inter-regional Theil index is always greater than the intra-regional Theil index, and the gap increases year by year. The above information indicates that the fairness of innovation resource allocation in provinces and cities within each major economic zone is high, while the fairness of innovation resource allocation among major economic zones has significant differences, and the difference situation has a further increasing trend.

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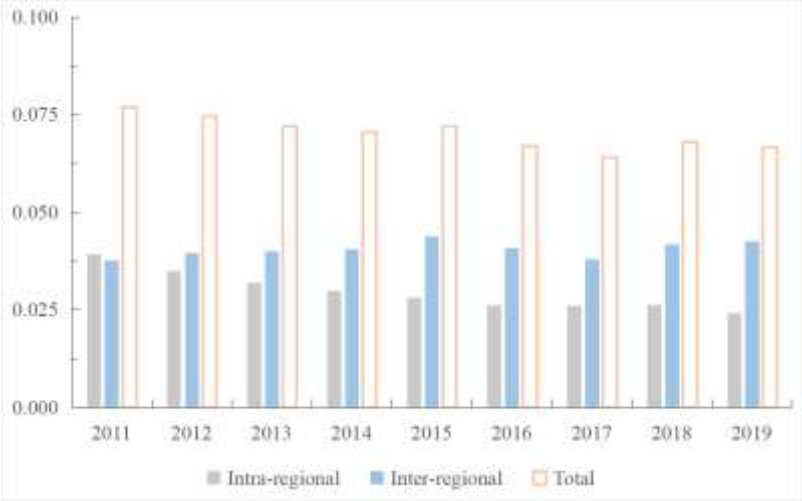

Fig 2: change trend of Theil index of regional innovation resource allocation from 2011 to 2019

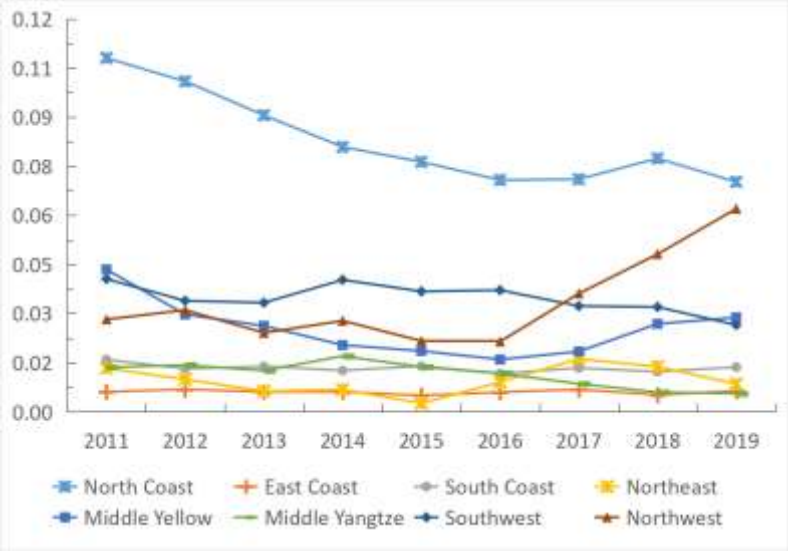

Fig 3: change trend of Theil index of regional innovation resource allocation from 2011 to 2019

(2) The fairness situation of regional innovation resource allocation. It can be seen in Fig 3 that, from the perspective of the overall change trend, there are different degrees of difference in the innovation resource allocation within the eight economic zones, but in the study year, there is an overall downward trend except the northwest area, which indicates that the fairness of innovation resource allocation in the major economic zones has been improved except the northwest area. From the perspective of the differences among economic zones, there are significant disequilibrium features, and there are obvious ladder levels. The northern coastal area is at the first level. And in the study year, its Theil index of total innovation resources is more than 0.070, which is significantly higher than that of other economic zones, indicating that there is a large gap in the innovation resource allocation among the northern coastal provinces, and the internal unfairness is the most obvious; The northwest area and the southwest area are at the second level. In the study year, the average values of the Theil index of total innovation resources in the two economic zones are respectively 0.035 and 0.033, which are at the midstream level. However, the

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Theil index of the northwest area has shown a significant growth trend after 2016, indicating that the fairness of innovation resource allocation among provinces in the northwest area has weakened in recent years; The middle reaches of the Yellow River, the southern coast and the middle reaches of the Yangtze River are at the third level. In the study year, the average values of the Theil index of total innovation resources in these three economic zones are respectively 0.025, 0.013 and 0.012; The northwest area and the eastern coast area are at the fourth level. In the study year, the average values of the Theil index of total innovation resources in the two economic zones are respectively 0.009 and 0.006. The internal provinces of the two areas have the smallest difference and the fairest innovation resource allocation.

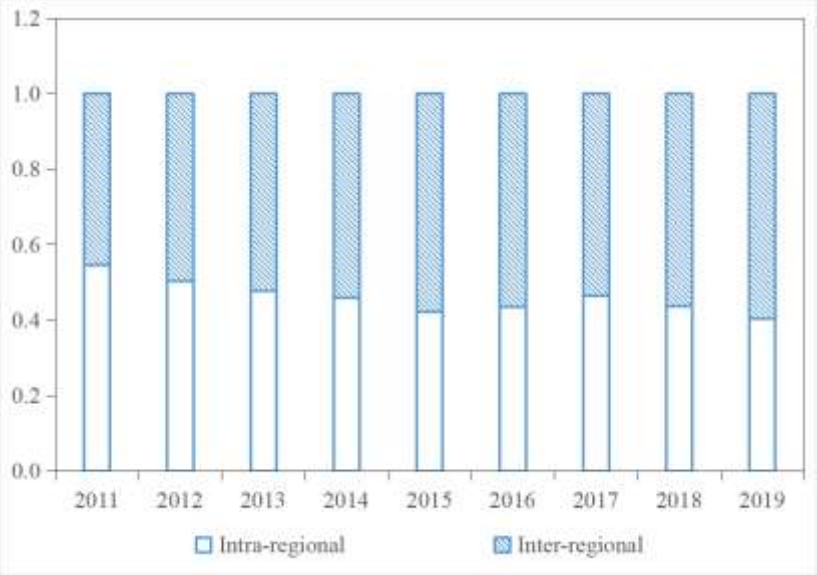

Fig 4: Contribution rate trend of regional differences to total differences from 2011 to 2019

TABLE II. Contribution rate of innovation resource allocation of differences in eight economic zones to differences in all areas from 2011 to 2019

Region	Time								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
North Coast	0.6596	0.6690	0.6615	0.6211	0.6466	0.6147	0.5864	0.5977	0.5619
East Coast	0.0404	0.0546	0.0527	0.0563	0.0480	0.0649	0.0728	0.0557	0.0740
South Coast	0.0642	0.0603	0.0680	0.0659	0.0760	0.0696	0.0838	0.0886	0.1053
Northeast	0.0219	0.0185	0.0122	0.0123	0.0041	0.0153	0.0268	0.0196	0.0139
Middle Yellow	0.0966	0.0714	0.0709	0.0584	0.0555	0.0520	0.0642	0.0803	0.0872
Middle Yangtze	0.0359	0.0435	0.0422	0.0645	0.0584	0.0538	0.0424	0.0273	0.0252
Southwest	0.0717	0.0691	0.0812	0.1081	0.1005	0.1178	0.1033	0.1046	0.0968
Northwest	0.0097	0.0136	0.0114	0.0133	0.0108	0.0119	0.0204	0.0262	0.0357

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(3) Difference contribution rate of regional differences to total differences. It can be seen in Fig 4 that, on the whole, the contribution rate of inter-regional differences was greater than that of intra- regional differences in the study year except 2011, indicating that the main reasons for the unfairness situation of the innovation resource allocation in China are the inter-regional differences of China' s eight economic zones. It can be seen in TABLE II that, in terms of subregions, the internal change trends of the eight economic zones are different. The difference contribution rate shows a downward trend in the four economic zones of the northern coastal area, the northeast area, the middle reaches of the Yangtze River and the middle reaches of the Yellow River. The difference contribution rate is always at a high level in the northern coastal area. The average contribution rate of this area is as high as 64.431% in the study yearand the fragmentation of innovation resource investment in this area is very obvious; The difference contribution rate in the northeast area shows a "U" trend, and its average annual decline rate during the study period is 4.060%; The difference contribution rate in the middle reaches of the Yangtze River decreased by 0.011during the study period, with an average annual decline rate of 3.320%; The middle reaches of the Yellow River have the smallest average annual change rate among the eight economic zones, and it is only 1.086%. In sharp contrast, the difference contribution rates of the eastern coast area, the southern coast area, the southwest area and the northwest area shows an upward trend. The difference contribution rates of the eastern coast and the southern coast increased, but the changes are great in general with an average annual increase rate of 9.243% and 7.120% respectively; The average annual growth rates of the southwest area and the northwest area are respectively 3.898% and 29.774%.The difference of innovation resource allocation in the northwest area has the smallest contribution to the difference of the total area during the study period. The reasons are not only that the total innovation resource investment in the northwest area has the smallest proportion, but also that the regional innovation resource allocation among provinces has small differences.

3.2 Spatial correlation features of fairness in regional innovation resource allocation

According to the measured Theil index value of innovation resource allocation in the eight economic zones, give it a positively standardization disposal and then the value of the fairness of innovation resource allocation in the eight economic zones can be obtained. Then, calculate the gravity matrix of China' s provincial innovation resource allocation fairness according to formula (5), and the gravity matrix is transformed into the correlation relationship matrix. On this basis, the correlation network density, average distance,average degree value and the number of subgroups can be calculated. It can be seen in details in Fig 5 and Fig 6.

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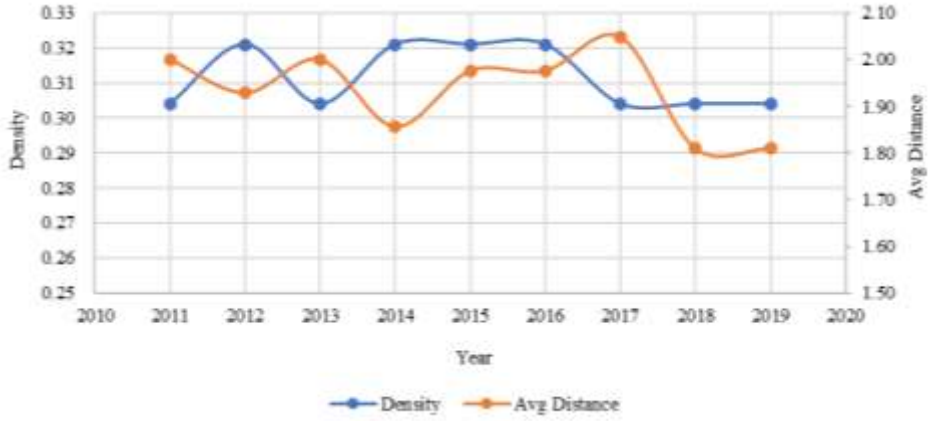

Fig 5: changes in the density and distance of fair related networks of innovation resource allocation in eight economic zones from 2011 to 2019

3.2.1Network density analysis

According to Fig 5, the correlation network density was about 0.30 in the study yearfrom the perspective of overall value of the fair correlation network density of innovation resource allocation in the eight economic zones, which indicates that the fair correlation network of innovation resource allocation in the eight economic zones has a certain foundation, but the degree of networking is not high and needs to be urgently strengthened; The distribution of fair correlation network density in the eight economic zones shows a complex trend of first increasing, then decreasing, then increasing again and decreasing again from the perspective of the change trend of network density. But the overall change range is small, it shows a downward trend, indicating that the relationship between regions has the weakening situation. The average distance also changes frequently, showinga downward trend in general from 2.00 in 2011 to 1.81 in 2019, which indicates that each economic zone can establish economic relationships with any other economic zone after passing through less than two economic zones on average.

3.2.2Network average analysis

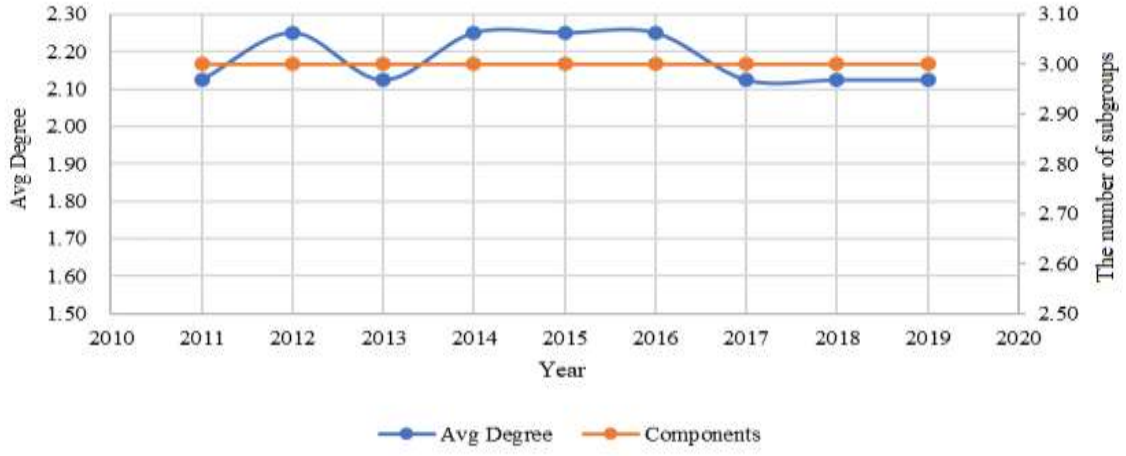

Fig 6: average value and subgroup change of fair correlation network of innovation resource allocation in eight economic zones from 2011 to 2019

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According to Fig 6, the average value of the network in the study year is more than 2 from the perspective of overall value of the average value of fair correlation network of innovation resource allocation in the eight economic zones. However, the maximum number of networks in the eight economic zones is 56 theoretically, and the maximum average value of the network is 8, indicating that although the fair correlation network of innovation resource allocation in the eight economic zones has a certain foundation, the networking degree is still not high and the cooperation in the innovation resource allocation in major economic zones needs to be strengthened; Generally speaking, it shows a downward trend from the trend of network average value in each year, indicating that the fair correlation of innovation resource allocation in major economic zones is further weakened. The number of subgroups is extremely stable, and the value obtained is 3 without any fluctuation in the study year.

3.2.3 Analysis of topological structure diagram of correlated network

Select four years of 2011, 2014, 2016 and 2019 as representatives to draw the topology diagram of fair correlation network of innovation resource allocation in eight economic zones. The results are shown in Fig 7.

According to Fig 7, it shows that the fair network of innovation resource allocation in the eight economic zones presents the following features: First, the overall correlation degree of the network in the four years is 1, indicating that the network has a good connectivity, and there are direct or indirect correlations between the node economic zones. There is no area separated from the network, that is, there are no isolated nodes in the correlated network, the allocation fairness at all levels may have spillover and spillover effects on other economic zones, and the economic intervals of each node in the network are interacted and influenced by each other. Second, the relationships of fair correlation of innovation resource allocation in the eight major economic zones are not close, and the spatial interaction is weak. The maximum number of network connections in the eight node provinces is 56 theoretically, while the actual number of connections in 2011, 2014, 2016 and 2019 are respectively 17, 18, 18 and 17. There are low network density, small average value of the network, and weak toughness and stability of the correlated network. Therefore, the linkage between the innovation resource allocation and the fair development of all economic zones should be made full use of, and the stability of cooperation among all major economic zones should be enhanced. Third, there is a large hierarchical ladder in the fair correlation degree of innovative resource allocation in the eight economic zones. The eastern coast area and the northern coast area have always been the main nodes in the fair correlation network, ranking the first level from the perspective of four years, which indicates that the two economic zones play an important role in the fair network of innovation resource allocation, and the spillover and spillover effects of the two economic zones are strong with other areas; The six economic zones in the middle reaches of the Yangtze River, the southern coast area, the middle reaches of the Yellow River, the northeast area, the southwest area and the northwest area rank the second level in the fair network of innovation resource allocation, with a small degree of centrality and limited influence in the network.

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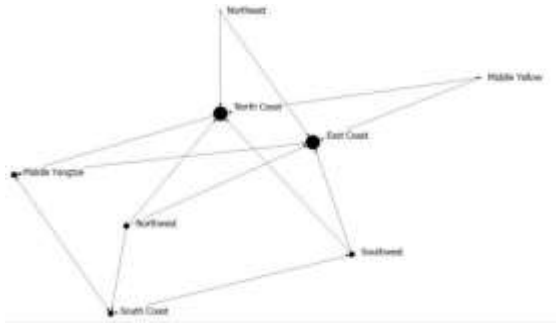
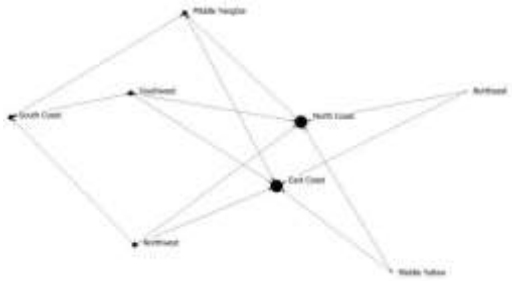
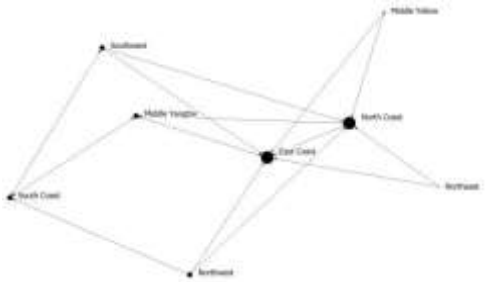


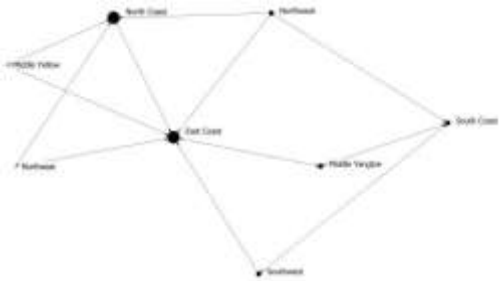
(a) 2011



(b) 2014



(b) 2016



(d) 2019

Fig 7: fair association network structure of innovation resource allocation in eight economic zones

IV. RESEARCH CONCLUSION

On the basis of the weighted relative Theil index, this study measures the fairness of innovation resource allocation of the whole China and its eight economic zones, and uses social network analysis to deeply explore its spatial correlation features. The following conclusions can be drawn.

First, there are significant differences in the fairness of regional innovation resource allocation, and there are obvious ladder levels existing. The northern coast area is at the first level, and it has the most obvious internal unfairness; The northwest area and the southwest area are at the second level, and the Theil indexes of innovation resources in these two economic zones are at the middle level during the study period; The middle reaches of the Yellow River, the southern coast area and the middle reaches of the Yangtze River are at the third level; The northeast area and the eastern coast area are at the fourth level, with the smallest difference among provinces, and the fairest allocation of innovation resources.

Second, the fairness of regional innovation resource allocation continued has been continually improved. The Theil index of innovative human resource allocation in China and the eight economic zones shows a stable trend and a slight increase during the study year; The Theil indexes of innovative financial resource allocation and innovative material resource allocation show a downward trend; The Theil index of total innovation resource allocation formed by the weighted synthesis of these three dimensions shows a downward trend, and it is indicated that the differences in innovation resource allocation of the whole country and each major economic zone have been alleviated and the fairness of innovation resource

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allocation has been improved.

Third, the differences in the regional innovation resource allocation are mainly reflected in inter-regional differences. During the study period, the contribution rate of inter-regional differences to overall differences continued to be greater than that of intra-regional differences to overall differences; And the intra-regional differences show a decreasing trend, and the inter-regional differences show an increasing trend; It shows that the main reason for the unfairness of innovation resource allocation in China is the regional difference of China's eight economic zones.

Fourth, there is a certain foundation in the fair correlation network of regional innovation resource allocation, but the resilience and stability of the network are weak. In the fair correlation network of innovation resource allocation, all nodes are interacted and influenced by each other, and all levels and regions can produce spillover and spillover effects; However, the degree of networking is not high, the spatial interaction is weak, and there is a further weakening trend during the study year.

Fifth, there is a large hierarchical ladder in the correlation situation of the fairness of regional innovation resource allocation, and the differences are significant. The eastern coast area and the northern coast area are always the main nodes in the fair allocation correlation network, ranking the first level, and have strong spillover and spillover effects with other regions; The six economic zones in the middle reaches of the Yangtze River, the southern coast area, the middle reaches of the Yellow River, the northeast area, the southwest area and the northwest area are at the second level in the fair correlation network of innovation resource allocation, and have limited influence in the network.

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