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Analysis of the Strength of China's Inter-Provincial Economic Linkage Intensity and Its Influencing Factors

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Abstract: The construction of the intensity of China's inter-provincial economic ties is of great significance to the spatial carrier of China's inter-provincial modern industrialization system**.** We uses entropy method, modified gravity model and grey correlation model to measure inter-provincial economic linkage intensity in 2019 and its influencing factors. The research shows that: (1) The strength of China's inter-provincial economic connection network is different, and the economic connection is not balanced. It is mainly concentrated in Beijing-Tianjin-Hebei region and Jiangsu-Zhejiang-Shanghai region. There is a certain coincidence between the economic connection network and the total economic connection intensity in space, and the economic development of each province is closely related to the connection between provinces. (2) The relationship between the China's inter-provincial economic linkage intensity and the gray correlation degree of each subsystem is infrastructure > social development > economic development > ecological environment protection > population and labor development. Among them, 6 subsystems have a correlation degree of 0.79 or more for the strength of interprovincial economic linkage, and the strongest correlation is 0.823 for infrastructure.

1. Introduction

Regional economic linkages is an important content of economic geography and other disciplines. Foreign scholars' earliest research on regional economic linkages can be traced back to Thünen's agricultural location theory. Weber 's industrial location theory, Perroux's growth pole theory, Myrdal's circular cumulative causality theory, Hirschman's unbalanced growth theory, and Friedman's "core-periphery" theory, which are used to explain the reasons for the partial agglomeration of spatial economy, regional economic development and mutual transmission [1]. Then, [2] proposed a "core-periphery" structure model based on the monopolistic competition model

and explained the prevalence of production factors in theory, and proved the rationality of the economic geography structure in terms of economic efficiency. Importantly, [3] further found that when the population size and land scale continue to expand to a certain threshold, the “core-periphery” structure will consist of multiple core regions to form a higher level of economic geography. Since then, [4] have tested the spatial connection of economic development between regions through the analysis of spatial panel data. [5,6] have studied the spatial accessibility, spatial flow and spatial structure in the study of regional economic linkages. In the early stage of domestic scholars, [7] systematically summarized, expounded and established the concept, system and basic mode of attraction scope, and put forward the division method to classify the attraction scop. [8] used the modified gravity model and grey correlation model to analyze the strength of geo-economic linkages between Hainan and its neighboring countries and its influencing factors. [9] used the annual average daily round-trip flow data between cities at the national and provincial highway observation stations, and used the Arc-GIS spatial analysis method to describe the city. On the basis of constructing economic linkages between cities, [10] introduced social network analysis to study the structural evolution and driving mechanism of economic networks in the Yangtze River Economic Belt.

Based on the modified gravity model, we calculated the economic linkage intensity of China's provinces (not included in the study due to the lack of data in Hong Kong, Macao and Taiwan, Xinjiang and Tibet) in 2019. Then we used the grey correlation model to analyze the inter-provincial economy of China, so as to obtain the structural characteristics of the spatial economic linkages between Hainan Province and other provinces and cities in China. It provides some theories and data for further optimizing the economic development policy and its path optimization with domestic and foreign economic linkages, it provides support for Hainan Free Trade Port to promote the formation of a new development pattern of domestic and international dual circulation and mutual promotion.

2. Research Methods and Data Sources

2.1. Data Sources

Our research is based on the “China Urban Statistical Yearbook”, “China Urban Construction Statistical Yearbook” issued by the National Bureau of Statistics, as well as the statistical yearbooks of various provinces and cities. Part of the completed data are extracted from the statistical bulletins of national economic and social development and government work reports of various provinces and cities. A small amount of missing data in individual provinces are interpolated by mean substitution method. In the above national data, due to the lack of data in Hong Kong, Macao and Taiwan, Xinjiang and Tibet, or incomplete statistics, it is not included in the study.

2.2. Construction of Index System

Previous scholars usually use a single indicator to represent the quality of the city when using the gravity model to calculate the degree of connection. A single indicator can only measure a single aspect of the level of urban economic development, and cannot comprehensively and scientifically measure the comprehensive strength of a province. Therefore, based on the principles of comprehensiveness, pertinence, comparability and operability, construct Table 1 Urban Comprehensive Strength Index Calculation Index System. The indicators constructed include 5 aspects: population and labor development, economic development, social development, infrastructure, ecological environment and protection. Among them, three representative indicators are selected for population and labor development, seven indicators that can reflect the level of urban economic development are selected for economic development. 9 indicators are selected for social development from 5 aspects of residents' income and consumption level, education, science, culture

and health services, information attention ability and social security. 4 indicators are selected for infrastructure, and 3 indicators closely related to ecology are selected for ecological environment and protection. The 26 indicators can objectively reflect the comprehensive level of cities in various provinces and cities.

Table 1: Urban Comprehensive Strength Index Calculation Index System

First-level indicators	Second-level indicators	Third-level indicators
Population and labor development	Population size	Permanent population (10000 people)
	Population Management and Applications	Number of unemployed persons of urban rank (persons)
		Natural growth rate of resident population (%)
Economic development	Economic scale	Gross regional product GDP (/billion CNY)
		Real estate investment (/billion CNY)
		Fiscal revenue (/billion CNY)
	Economic structure	The proportion of secondary industry in GDP
		The proportion of tertiary industry in GDP
	Economic growth	GDP growth (%)
	Economic benefits	Per capita regional GDP (CNY / person)
Social development	Residents' income and consumption level	Per capita consumption expenditure (CNY)
		Per capita disposable income (CNY / person)
	Housing services	Total number of hospital beds (sheets)
	Education, science, culture and health services	Science and education expenditure (CNY 100 million)
		Number of college students (/persons)
		Number of libraries per capita (volume)
	Information attention ability	Internet attention
	Social security	The number of employees participating in the basic old-age insurance (ten thousand)
		The number of people participating in the basic medical insurance for employees (ten thousand)
Infrastructure	Communication	Total post and telecommunications business (/10000CNY)
		Internet with access to the number of users (/1 million)
	Water Supply, Drainage and Electricity	Drainage pipe length (/10000 kilometers)
		Annual electricity consumption (kilowatt hours)
Ecological environment and protection	Waste treatment	Centralized treatment rate of sewage treatment plant (%)
	Urban greening	Urban park green area (hectare)
		Urban greening coverage (%)

2.3. Research Methods

2.3.1. Modified Gravity Model Construction

The gravity model in economic geography is gradually evolved based on Newton's universal gravity model, which is mainly used to predict the flow of human, information and goods between

cities, regions and even countries [11]. This model is widely used in the field of economic geography, and has been continuously improved and revised to form a rich theoretical system of economic gravity model. In the economic field of provinces and cities, the gravity model can measure the economic links between provinces and cities. The formula is:

$$F_{ij} = k\frac{M_i M_j}{D_{ij}^b} \tag{1}$$

Among them: $F_{ij}$is the gravitational value between provinces and cities; M_i and M_j represent the economic development level of i and j respectively; D_{ij} denotes the distance between provinces and cities.

For getting a more objective inter-provincial contact distance, we use the time cost of transportation, the monetary cost of transportation, and the linear spatial distance between provincial capitals. The formula is as follows:

$$D_{ij} = (\sum_{k=1}^{n} \lambda_k C_{ij} T_{ij} L_{ij})^b \tag{2}$$

$D_{ij}$is the distance between province i and province j, λ_k represents the weight value of the kth transportation mode, C_{ij} represents the monetary cost of the kth transportation mode from province i to province j, T_{ij} is the time cost of the kth transportation mode from province i to province j, L_{ij} represents the linear spatial distance from province i to province j, and b represents the distance attenuation index. After referring to the relevant research results, the gravitational coefficient K and the distance attenuation coefficient b are both taken as 1.

2.3.2. Grey Correlation Model

In the geographical system, the relationship between many factors is grey. The time series data is dynamic, so it is hard to distinguish the primary and secondary influencing factors. The grey correlation model can effectively solve the above problems. It can quantitatively analyze the dynamic development process of the system, and reveal the dominant factors and secondary factors affecting the development status of the system through the consistency of the similarity of the changes between the system factors. This model is widely used in geography research. The calculation formula is as follows:

$$\xi_i(k) = \frac{\min\limits_i \min\limits_k \cdot |x_0(k) - x_i(k)| + \rho \cdot \max\limits_i \max\limits_k \cdot |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \cdot \max\limits_i \max\limits_k \cdot |x_0(k) - x_i(k)|} \tag{3}$$

$$R_i = \frac{1}{N}\sum_{k=1}^{N} \xi_i(k) \tag{4}$$

In the formula: $|x_0(k) - x_i(k)|$ is the absolute difference between the mother sequence of the kth province and the influencing factor i; ρ is the resolution coefficient, the value range is between 0-1, and the experience is generally considered to take 0.5; N is the number of provinces and cities.

3. Results and Analysis

3.1. Measurement of Urban Comprehensive Strength Level

The original data in the index system established above are standardized by range, and the relevant

weights of each economic index in the index system are calculated by entropy method. The weights are shown in Table 2:

Table 2: Index Weight Table of Urban Comprehensive Strength Level

No.	Specific index	weight	No.	Specific index	weight
1	Permanent population (10000 people)	3.85%	15	Total number of hospital beds (sheets)	4.10%
3	Number of unemployed persons of urban rank (persons)	2.25%	16	Science and education expenditure (/CNY 100 million)	3.78%
4	Natural growth rate of resident population (%)	3.18%	17	Number of college students (persons)	4.38%
5	Gross regional product GDP (/billion CNY)	4.55%	18	Number of libraries per capita (volume)	5.44%
6	Investment in fixed assets (/billion CNY)	4.63%	19	Internet attention	3.61%
8	Fiscal revenue (/billion CNY)	5.20%	20	The number of employees participating in the basic old-age insurance (/10000 people)	4.51%
9	The proportion of secondary industry in GDP	1.19%	21	The number of employees participating in basic medical insurance (/10000 people)	5.29%
10	The proportion of tertiary industry in GDP	5.46%	22	Total post and telecommunications business (/10000 CNY)	4.73%
11	GDP growth (%)	1.26%	23	Internet with access to the number of users (million)	3.99%
12	Per capita regional GDP (CNY / person)	4.48%	24	Drainage pipe length (/10000kilometers)	5.61%
13	Per capita consumption expenditure (CNY)	5.37%	25	Annual electricity consumption (kilowatt hours)	4.46%
14	Per capita disposable income (CNY)	2.83%	26	Centralized treatment rate of sewage treatment plant (%)	0.60%
15	Total number of hospital beds (sheets)	4.10%	27	Urban park green area (hectare)	4.04%
16	Science and education expenditure (CNY 100 million)	3.78%	28	Urban greening coverage rate	1.21%

3.2. Analysis on the Inter-Provincial Economic Linkage Intensity

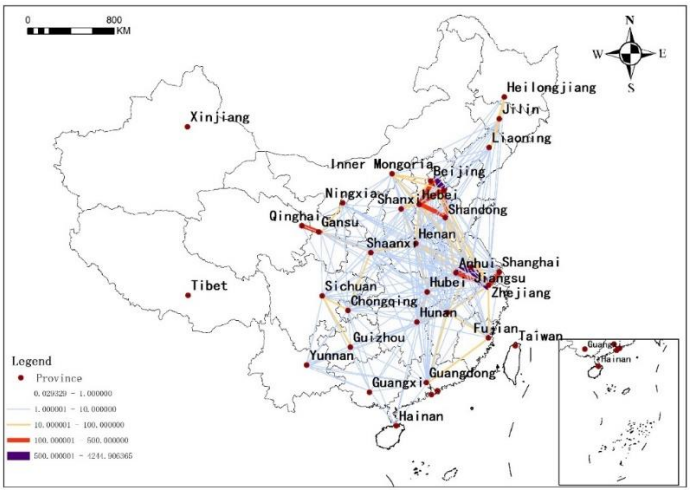

Figure 1: China's Inter-Provincial Economic Linkages Network Diagram

Figure 2: Spatial Distribution Map of China's Economic Linkages Intensity

The economic connection intensity network between provinces in China is different and the economic linkage is not balanced (Fig.1). It is mainly concentrated in Beijing-Tianjin-Hebei region and Jiangsu-Zhejiang-Shanghai region. In the Beijing-Tianjin-Hebei region, Beijing, Tianjin, Hebei and Shandong have strong economic linkages, showing gradient distribution characteristics. The economic linkages between Beijing and Tianjin are in the first echelon. Beijing and Tianjin account for 85.42 the total inter-regional economic linkages. The coordinated development of Beijing, Tianjin and Hebei is a major national strategy in China. The 3 sides actively promote the economic development of the three parties by virtue of their geographical advantages and industrial cooperation. The inland hinterland of Shandong is adjacent to Hebei, the coastal north is connected with Beijing and Tianjin channels. The south is connected with Anhui, Jiangsu, Zhejiang and Shanghai, connecting the 2 major economic zones of the north and the south. However, the connection between Shandong and the Beijing-Tianjin-Hebei region is closer than that between Jiangsu, Zhejiang and Shanghai. In Jiangsu, Zhejiang and Shanghai, the economic linkages between Anhui, Shanghai, Zhejiang and Jiangsu are closer, while the economic linkages with other provinces are smaller.

The total intensity of economic linkage reflects the communication between the province and the outside world, and the gap in the total economic linkages between provinces reflects the imbalance

of economic linkages between provinces in China (Fig.2). Based on the modified gravity model, the total economic linkage of Tianjin is as high as 9716.51, while the minimum economic connection strength of Hainan Province is only 38.56, which is 251 times different. There is a certain overlap between the economic connection network and the total economic connection intensity in space. The total economic connection of several major urban agglomerations in China, Beijing-Tianjin-Hebei, Jiangsu-Zhejiang-Shanghai, Anhui-Jiangnan and Chengdu-Chongqing regions is significantly higher than that of other regions, and these regions are also economically developed regions, so the economic development of each province is closely related to the inter-provincial linkage.

3.3. Analysis of the Influencing Factors of China's Inter-Provincial Economic Linkage Intensity

Table 3: Grey Correlation Statistical Table

System type	Grey correlation	Influencing factor	Grey correlation
Population and labor force development	0.790	Permanent population (10000people)	0.803
		Number of unemployed persons of urban rank (persons)	0.797
		Natural growth rate of resident population (%)	0.77
Economic development	0.808	Gross regional product GDP (/billion CNY)	0.827
		Real estate investment (/billion CNY)	0.828
		Fiscal revenue (/billion CNY)	0.835
		The proportion of secondary industry in GDP	0.788
		The proportion of tertiary industry in GDP	0.788
		GDP growth (%)	0.782
		Gross regional product per capita (CNY / person)	0.81
Social development	0.813	Per capita consumption expenditure (CNY)	0.813
		Per capita household savings deposits (CNY / person)	0.82
		Total number of hospital beds (sheets)	0.796
		Science and education expenditure (CNY 100 million)	0.812
		Number of college students (persons)	0.817
		Number of libraries per capita (volume)	0.816
		Internet attention	0.799
		The number of employees participating in the basic old-age insurance (ten thousand)	0.817
		The number of employees participating in basic medical insurance (ten thousand people)	0.825
Infrastructure	0.823	Total post and telecommunications business (ten thousand CNY)	0.819
		Internet with access to the number of users (million)	0.817
		Drainage pipe length (km)	0.834
		Annual electricity consumption (kilowatt hours)	0.821
Ecological environment and protection	0.799	Centralized treatment rate of sewage treatment plant (%)	0.787
		Urban Park green area (hectare)	0.82
		Urban greening coverage rate	0.789

The influence mechanism of inter-provincial economic linkage intensity is complex and affected by many factors. This paper uses the grey correlation model to quantitatively analyze the influencing factors of China's inter-provincial economic linkage intensity. Taking inter-provincial economic linkage intensity as the mother sequence, this paper constructs 26 influencing factors of 6 subsystems of population and labor development, economic development, social development, infrastructure,

ecological environment and protection, and analyzes the relationship between the mother sequence and the subsequence.

The results from table 3 show that the relationship between the intensity of China's inter-provincial economic linkages and the grey correlation of each subsystem is infrastructure > social development > economic development > ecological environment and protection > population and labor development. Infrastructure is an important support for economic development and plays a leading role in the real economy. It is the basis for the unified economic development, social and ecological benefits. The better the infrastructure development of a province, the better the annual electricity consumption, the total post and telecommunications business, and the number of Internet broadband access users can intuitively reflect the ability of the region to communicate with the outside world, so its grey correlation degree reaches 0.823. Social development has promoted the economic development of various provinces and cities in terms of per capita household savings deposits, regional Internet attention, and per capita consumption expenditures. Social development and economic development complement each other. The better the economic development of a region, the stronger the ability to radiate outward, and the better it can drive the development of surrounding provinces and cities and its own. Coordinating the development relationship among economy, ecological environment and social welfare is the focus of sustainable development, and it is also the inherent requirement of practicing the concept of high-quality development. Therefore, although the explanatory ability of ecological environment and protection is weaker than that of other subsystems, its correlation with economic connection degree still reaches 0.799.

4. Conclusions and Discussion

4.1. Conclusions

We use the entropy method and the modified gravity model, as well as the grey correlation model, to measure the intensity of China’s inter-provincial economic linkages in 2019 and its influencing factors. Based on the analysis and research results, the following conclusions are drawn.

(1) China’s inter-provincial economic linkages network strength is different, economic linkages are not balanced. It is mainly concentrated in Beijing-Tianjin-Hebei region and Jiangsu-Zhejiang-Shanghai region. There is a certain coincidence between the economic connection network and the total amount of economic connection intensity in space. The economic development of each province is closely related to the connection between provinces.

(2) The results from Table 3 show that the relationship between the intensity of China’s inter-provincial economic linkage and the grey correlation of each subsystem is infrastructure > social development > economic development > ecological environment and protection > population and labor development. Among them, the correlation degree of six subsystems to the inter-provincial economic linkage intensity is above 0.79, and the strongest correlation is that the infrastructure is 0.823.

4.2. Discussion

Due to the availability of data and the complexity of interprovincial economic linkage activities, there are still some areas for improvement and improvement in this study, which need to be further studied in the future. In the future, it is necessary to deeply explore the new pattern and new dynamics of inter-provincial economic relations under the new situation. Since the reform and opening up, under the background of the increasingly full role of the market, the inter-provincial economic ties have been continuously strengthened, the trend of factors flowing to a better environment has become stronger and stronger, and the traditional pattern of inter-city economic ties based on administrative

boundaries "drawing land as a prison" has been constantly changing, which requires clarification of the new structure and new pattern of the inter-city economic connection network in the new period.

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