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Analysis of Regional Economic Development Level in Sichuan Province based on Grey Clustering Model

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Abstract: ***Objective:*** *Conduct a study on the spatial economic connections of the urban agglomerations in Sichuan Province region, analyze its current situation, characteristics, and problems, and provide a basis for strengthening the spatial economic connections of the urban agglomerations in Sichuan Province region.* ***Methods:*** *Comprehensively apply methods such as literature review, theoretical analysis, qualitative analysis, and quantitative calculation. Measure and analyze the intensity and direction of the spatial economic connections of the Chengdu - Chongqing urban agglomeration by improving the gravity model, economic affiliation index, and other means.* ***Conclusions:*** *1) The overall spatial economic connections of the urban agglomerations in Sichuan Province region are loose. 2) The influence of Chengdu extends in a radial pattern towards southern Sichuan and northeastern Sichuan. 3) The economic connection directions of the urban agglomerations in Sichuan Province region are obviously directional. 4) The main economic connection direction of Chengdu is the Chengdu - Deyang - Mianyang - Leshan development axis.*

Keywords: Urban agglomerations in Sichuan Province region, Gravity model, Spatial economic connection.

1. Introduction

Since the reform and opening up, the urbanization process in China has continued to advance, and accelerating the construction of urban agglomerations has gradually become a social consensus and the mainstream trend of regional economic development. Reilly [1] put forward the "Law of Retail Power", which holds that the sales volume of a store is directly proportional to its own production scale and inversely proportional to the square of the distance. Zipf [2] applied the gravity model to the analysis of spatial interaction between cities, laying the foundation for the theoretical research on the spatial interaction of urban agglomerations. The growth pole theory of Perroux [3] and the core-periphery theory of Friedmann [4] laid the theoretical foundation for the study of urban economic spatial structure and urban system. Friedmann [5] believed that innovation spillover is an important factor in interregional connections, and innovation spillover can explain interregional connections to some extent. Rykiel [6] proposed that there are hierarchical and non-hierarchical connections in the urban structure. In the process of urban system development, hierarchical connections will gradually transform into non-hierarchical connections, the connections related to the central place function will remain stable, and the connections related to the specialized function may change. Kiyoshi Kobayashi [7] studied the impact of rapid transportation on urban interaction, urban scale distribution and urban spatial structure based on the high-speed railway system. Zhou Yixing and Hu Zhiyong [8] revealed the structural framework of China's urban system by analyzing the structural characteristics of the aviation network. Gu Chaolin and Pang Haifeng [9] calculated the intensity of spatial connections between Chinese cities through the gravity model and described the spatial connection status and nodular area structure of China's urban system. Hou Yunhui and others [10] analyzed the economic structure of the Yangtze River Delta urban agglomeration by using the social network analysis method. Xu Huichao and others [11] measured the urban flow intensity of 28 cities in the Central Plains Economic Zone by using the urban flow intensity model and analyzed the temporal and spatial evolution law of the urban flow intensity in the Central Plains Economic Zone. Miao Changhong and Wang Haijiang [12] calculated the economic connection intensity between cities in Henan and provincial capitals across the country and concluded that there is a extremely strong linear correlation between the economic connection quantity and the traffic connection quantity. Chen Jinwei and others [13] believed that factors such as the transformation and upgrading of economic structure, the strengthening of regional integration policies and the construction of regional transportation infrastructure will affect the flow of resource elements in the Pearl River Delta. Wang Haijiang [14] found that the central city exerts the functions of inward agglomeration and outward diffusion through the outward service function, forming complex economic flows between cities, thus affecting and strengthening the regional spatial structure. Lan Fujun [15] explored the main causes and influencing factors of the economic spatial differentiation in the Chengdu-Chongqing Economic Zone and pointed out that the main obstacle to the optimization of the economic spatial structure in the Chengdu-Chongqing Economic Zone is the inconsistency between the administrative division and the economic zone division caused by the separation of Chengdu and Chongqing. Wu Fang and others [16] measured the industrial economic connections between Chengdu and Chongqing by using the gravity model and the break point model and found that the comparative advantage industries in Chengdu are capital and labor-intensive industries, while the comparative advantage industries in Chongqing are resource and technology - intensive industries, but there is an industrial convergence phenomenon between the two places and the overall industrial economic connection is weak. Huang Qin and Liu Suqing [17] analyzed the current characteristics of the economic network structure of the Chengdu-Chongqing urban agglomeration by using the economic connection model and the social network analysis method and believed that the "core-periphery" structure of the Chengdu-Chongqing twin cities is obvious, but due to the low overall connection level, the real urban agglomeration in the Chengdu-Chongqing area has not yet formed. Yin Hongpan [18] improved the gravity model in combination with the actual situation of China's low

urbanization rate, analyzed the spatial economic pattern and intercity economic correlation of the Chengdu-Chongqing urban agglomeration and put forward the problem that the border area between Sichuan and Chongqing is facing the risk of marginalization.

As a major economic province in western China, Sichuan Province's regional economic development not only relates to the implementation of the national "Western Development" strategy but also serves as a key node for the connection between the Yangtze River Economic Belt and the "Belt and Road Initiative". However, the problem of uneven economic development within Sichuan Province is significant: the Chengdu Plain Economic Zone, relying on the radiation effect of the provincial capital Chengdu, has formed a relatively high degree of economic agglomeration, while the northeastern, southern and northwestern regions of Sichuan are constrained by geographical conditions, lagging transportation infrastructure and homogeneous industrial competition, resulting in relatively backward economic development. In recent years, the Chengdu-Chongqing Twin-City Economic Circle has been elevated to a national strategy, but the cross-administrative region coordination mechanism has not yet been fully established, and the mismatch between administrative and economic divisions still hinders the process of regional integration. Existing research mostly focuses on the interaction between single cities or the Chengdu-Chongqing twin cities, and systematic analysis of the spatial economic connections of the entire urban agglomeration in Sichuan Province is still insufficient. This study attempts to reveal the spatial differentiation laws of economic connections among urban agglomerations in Sichuan Province by improving the gravity model and grey clustering method, providing a scientific basis for breaking administrative barriers and optimizing resource allocation.

2. Basic Concepts and Related Theories

This paper believes that the urban agglomeration is an organizational form of economic activities with cities as the basic carrier within a certain region. This region takes one or several super-large and mega-cities as the core and distributes a large number of cities of different types and scales. Cities conduct economic and social exchanges through a relatively dense transportation network, forming a city collective with division of labor and cooperation, close connection, high urbanization level and economic integration tendency.

There are cross-regional flows of population, goods, information and other aspects between cities, forming various connections, which are collectively called spatial connections. Spatial economic connections are cross-regional connections generated based on various economic activities of various micro-economic activity subjects. The manifestation is the interaction and exchange of various economic elements between cities, that is, the interweaving and flowing of elements such as goods, population, capital and information between cities through interconnected transportation facilities.

All kinds of economic activities between different cities objectively form the division of labor in the labor area. Each city undertakes different functions in the industry and market, thus generating the exchange and interaction of economic elements between cities. Division of labor and cooperation promote the urban agglomeration to achieve the optimal allocation of resources and obtain economic benefits far exceeding the simple superposition of individual cities by using the resource endowment and factor flow.

With the increase of spatial distance, the cost increase caused by the rise of transportation cost will eventually offset the cost savings caused by the decrease of land price and labor cost, and the total economic cost will increase with the increase of spatial distance. The economic connections between regions will decrease with the increase of spatial distance, that is, the principle of spatial distance attenuation.

The spatial economic connection mechanism of urban agglomerations promotes the coordinated allocation of resources in urban agglomerations and obtains economic benefits far greater than the simple superposition of individual cities by promoting the flow of factors. It is the internal law to promote the integrated development and play a strategic role of urban agglomerations.

The theory of main economic connection direction holds that the city is an open system and has mutual connections with other regions. However, due to the heterogeneity of space, the degree of the city's external connection is also different. The expansion of the city will follow the principle of least effort and extend to the main economic connection direction first. It can provide a theoretical basis for the determination of the economic location of each city in the urban agglomeration and the identification of the main economic connection direction.

As an effective tool for dealing with "small sample, poor information" systems, the grey clustering model's core lies in quantifying the correlation degree among indicators through grey relational analysis, and then classifying and evaluating complex systems. In regional economic analysis, the grey clustering model can overcome the traditional statistical method's reliance on complete data, and is particularly suitable for underdeveloped regions like Sichuan Province where data acquisition is difficult. Specifically, this study incorporates indicators such as economic connection strength, transportation accessibility, and industrial structure complementarity into the grey clustering system, determines the threshold intervals of each indicator through the whitening weight function, and ultimately achieves the dynamic classification of economic connection levels among urban agglomerations. Additionally, the "core-periphery" theory in new economic geography provides significant support for this study: core cities (such as Chengdu) exert polarization and diffusion effects on surrounding cities through mechanisms like knowledge spillover and capital flow, while the reduction of transportation costs may reshape the spatial pattern of economic connections. The combination of this theoretical framework with the gravity model can more comprehensively explain the non-equilibrium characteristics of economic connections among urban agglomerations in Sichuan Province.

3. Study Subjects and Research Methods

3.1 Study Subjects

Based on the "Chengdu-Chongqing Urban Agglomeration Development Plan", considering factors such as the contiguous situation of the built-up areas of various districts and counties, the geographical distance, the subordinate situation before the direct jurisdiction and the availability of statistical data, this paper takes 15 prefecture-level cities in Sichuan as 15 urban units. Calculate and analyze the results of the spatial economic connections of the urban agglomerations in Sichuan province region, study the main economic connection directions and the connection intensity of each city in the urban agglomerations in Sichuan province region, divide the hinterland of the core city accordingly, explore the restricting factors of economic connections and put forward relevant countermeasures to strengthen the spatial economic connections of the urban agglomerations in Sichuan Province region on this basis.

3.2 Study Methods

3.2.1 Literature and data method

Through the collection of a large number of materials and the reading of literature, comb the relevant theories of the economic basic theory of urban agglomerations, the theory of spatial interaction and the spatial economic connection between cities and the research on the relevant topics in the Sichuan province region, master the research trends of domestic and foreign scholars and describe the economic development overview of the urban agglomerations in Sichuan Province region.

3.2.2 Theoretical analysis method

Combing the relevant theories of urban spatial economic connection in regional economics, analyzing the action mechanism and providing theoretical support for measuring the intensity and direction of economic connection of urban agglomerations.

3.2.3 Qualitative analysis method

Analyze the main contents and research perspectives of urban economic connections, summarize the current development status of each city in the urban agglomerations in Sichuan Province region and the phased characteristics of economic connections between cities and put forward some strengthening countermeasures for the spatial economic connections of the urban agglomerations in Sichuan Province region.

3.2.4 Quantitative calculation method

Measure the intensity and direction of the spatial economic connections of the urban agglomerations in Sichuan Province region by improving the gravity model, the economic membership index and other ways and then analyze the restricting factors of its spatial connections.

4. Results and Analysis

4.1 Selection and Improvement of the Gravity Model

4.1.1 Selection of the Gravity Model

The gravity model, by drawing on the law of universal gravitation and based on spatial interaction and spatial proximity effects, can measure the intensity of economic connections between cities. It is operable and easy to modify.

The basic form of the gravity model is shown in the formula:

$$Y = k\frac{M_i M_j}{D_{ij}^2} \quad (1)$$

Where Y represents the intensity of connection between two regions, M_i and M_j respectively represent the "mass" indicators of regions i and j, D_{ij} represents the distance between the two regions, and k is a constant.

4.1.2 Improvement of the Gravity Model

According to existing research, scholars believe that the "mass" of a region is positively correlated with its population size and economic scale. Based on this, the gravity model is modified to obtain the classic gravity model for regional economic connections:

$$Y = \frac{\sqrt{P_i G_i}\sqrt{P_j G_j}}{D_{ij}^2} \quad (2)$$

Where P_i and P_j respectively represent the population of regions i and j, and G_i and G_j respectively represent the economic scales of regions i and j.

To accurately measure the intensity of economic connections between cities, this paper will modify the gravity model in two aspects. On one hand, it can be considered that the measurement indicators of "urban mass" should be selected according to the economic connection mechanism and the flow of economic factors. On the other hand, the urban distance essentially refers to the transportation cost between two places, so it is necessary to comprehensively consider the optimal means of transportation and transportation costs.

This paper selects the following indicator system for "urban mass": 9 indicators including gross regional product, permanent urban population, growth rate of gross regional product, per capita gross regional product, per capita disposable income of urban residents, total fixed - asset investment, total retail sales of consumer goods, local fiscal revenue, and urbanization rate, representing production capacity, market capacity, growth rate, labor productivity, income level, capital conversion ability, market consumption ability, public service ability, and urban construction level respectively. The formula is as follows:

$$M_i = \sum_j A_{ij}^* \times \theta_j \quad (3)$$

Where M_i represents the "urban mass" indicator of city i, A_{ij}^* represents the standardized value of the j-th indicator of city i, and θ_j represents the weight of the j-th indicator.

To avoid the influence of different dimensions of evaluation indicators, this paper first processes the data using the deviation standardization method. The formula is as follows:

$$A_{ij}^* = \frac{A_{ij} - min(A_j)}{max(A_j) - min(A_j)} \times 1000 \quad (4)$$

Where A_{ij}^* represents the standardized value of the j-th indicator of city i; A_{ij} represents the original value of the j-th

indicator of city *i*.

This paper uses the coefficient of variation method to measure the indicator weights. The formula is as follows:

$$\begin{cases} \varepsilon_j = \frac{\sigma_j}{\delta_j} \\ \theta_j = \frac{\varepsilon_j}{\sum \varepsilon_j} \end{cases} \quad (5)$$

Where ε_j represents the coefficient of variation of the *j*-th indicator, σ_j represents the standard deviation of the *j*-th indicator, δ_j represents the average of the *j*-th indicator, and θ_j represents the weight of the *j*-th indicator.

The urban distance is measured from two aspects: average travel time and average transportation cost. The formula for measuring the urban distance is:

$$\begin{cases} D = \sqrt{(W_h T_h + W_r T_r) \times (W_h C_h + W_r C_r)} \\ W_h = \frac{1}{2}\left(\frac{Q_h}{Q_h+Q_r} + \frac{S_h}{S_h+S_r}\right) \\ W_r = \frac{1}{2}\left(\frac{Q_r}{Q_h+Q_r} + \frac{S_r}{S_h+S_r}\right) \end{cases} \quad (6)$$

Where D represents the distance between two cities, W_h represents the weight of road transportation, W_r represents the weight of railway transportation, T_h represents the road travel time, T_r represents the railway travel time, C_h represents the road transportation cost, C_r represents the railway transportation cost, Q_h represents the road passenger volume, Q_r represents the railway passenger volume, S_h represents the road freight volume, and S_r represents the railway freight volume.

The expression of the gravity model for the urban agglomerations in Sichuan province region is obtained as follows:

$$\begin{cases} Y_{ij} = \frac{M_i M_j}{D_{ij}^2} \\ D_{ij} = \left(\sqrt{(W_h T_h + W_r T_r) \times (W_h C_h + W_r C_r)}\right)_{ij} \end{cases} \quad (7)$$

Where Y_{ij} represents the spatial economic connection intensity between city *i* and city *j*, M_i and M_j respectively represent the "mass" indicators of regions *i* and *j*, D_{ij} represents the distance between cities *i* and *j*, W_h represents the weight of road transportation, W_r represents the weight of railway transportation, T_h represents the road travel time, T_r represents the railway travel time, C_h represents the road transportation cost, and C_r represents the railway transportation cost.

4.1.3 Economic Affiliation Degree Model

The economic affiliation degree refers to the proportion of the economic connection intensity between two cities in the total economic connection intensity of a city, reflecting the attraction and radiation ability of the central city to the surrounding cities. Its calculation formula is:

$$F_{ij} = \frac{Y_{ij}}{\sum_{j=1}^{m} Y_{ij}} \quad (8)$$

Where F_{ij} represents the economic affiliation degree of city *i* to city *j*, and *m* represents the number of other cities in the urban agglomeration.

4.2 Calculation of Economic Connection Intensity

First, the data of "urban mass" evaluation indicators are processed by the coefficient of variation method, that is, formula (3), to obtain the weight table of each indicator as shown in Table 1.

Table 1: "Urban Mass" Evaluation Indicators

Indicator	Indicator Significance	Weight
Gross Regional Product	Production Capacity	0.166
Permanent Urban Population	Market Capacity	0.139
Growth Rate of Gross Regional Product	Development Speed	0.028
Per Capita Gross Regional Product	Labor Productivity	0.056
Per Capita Disposable Income of Urban Residents	Income Level	0.035
Total Fixed - Asset Investment	Capital Conversion Ability	0.134
Total Retail Sales of Consumer Goods	Urban Consumption Ability	0.173
Local Fiscal Revenue	Urban Government Ability	0.204
Urbanization Rate	Urban Development Level	0.065

Secondly, according to the statistical data and indicator weights, the "urban mass" of the Chengdu - Chongqing urban agglomeration in 2017 is calculated by formula (3).

Then, according to formula (6), the weight of road transportation is calculated to be 0.93 and the weight of railway transportation is 0.07, and then the calculation results of urban distance can be obtained.

Finally, the improved gravity model, that is, formula (7), is used to calculate the spatial economic connection intensity between each city in the urban agglomerations in Sichuan province region, the sum of the economic connection intensities of each city in the urban agglomerations in Sichuan province region, and its proportion in the total economic connection intensity in the region. It can be seen that the economic connection intensities of Chengdu rank first in the urban agglomerations in Sichuan province region respectively. Cities with the weakest economic connection intensities almost all located on the northeast edge of the Sichuan Basin.

4.3 Analysis of Economic Connection Intensity

According to the calculation results, the economic connection intensity between cities is classified. The economic connection intensity is divided into five levels to represent the degree of spatial economic connection between cities, namely extremely strong connection, strong connection, medium - intensity connection, weak connection, and extremely weak connection. The classification results are shown in Table 2.

Table 2: Classification of Connection Degrees in the Chengdu - Chongqing Urban Agglomeration

Degree of Connection	Value Range	Number of City Groups	Proportion of Groups	Sum of Connection Intensities	Proportion of Sum of Intensities
Extremely Strong Connection	≥60	2	0.3%	153.5	9.2%
Strong Connection	30~60	5	0.8%	206.1	12.3%
Medium - Intensity Connection	10~30	29	4.6%	527.7	31.5%
Weak Connection	1~10	218	34.6%	643.5	38.4%
Extremely Weak Connection	≤1	376	59.7%	143.8	8.6%

The average economic connection intensity of the urban agglomerations in Sichuan Province region is only 2.7, and the median is only 0.7. The spatial economic connections between most cities are still in a relatively loose stage, and the scale effect of the urban agglomeration has not been fully exerted. There are a total of 36 city groups with a medium - intensity connection or above. With a proportion of 5.7% of the number of city groups, they contribute 53.0% of the economic connection intensity of the entire urban agglomeration, which is the supporting force for the spatial economic connection of the urban agglomerations in Sichuan Province region. There are a total of 594 city groups with weak and extremely weak connections in the entire urban agglomeration, accounting for 94.3% of the total number of city groups, and the sum of their economic connection intensities accounts for 47.0% of the total intensity, which can represent the degree of economic connection tightness of the entire urban agglomerations in Sichuan Province region.

The distribution pattern of spatial economic connections has significant regional characteristics. Based on the city groups with a medium - intensity connection or above, it is a radial spatial economic connection structure centered on Chengdu and radiating to the Chengdu Plain urban belt, the southern Sichuan urban - intensive area, and the Nansui - Guang urban - intensive area. The economic connections between cross - provincial cities in the border area between Sichuan and Chongqing are weak. Cities belonging to Sichuan basically only have economic connections within their respective provinces or municipalities. From this perspective, the urban agglomerations in Sichuan Province region has not formed a whole. The Dawan urban - intensive area located on the northeast edge of the Sichuan Basin is still in the cultivation stage.

4.3.1 Typical case: The economic relationship between Chengdu and Mianyang

The value of economic connection intensity between Chengdu and Mianyang is 58.7, which belongs to the category of "strong connection". From the perspective of industrial collaboration, Chengdu's high-end industries such as electronic information and financial services complement Mianyang's military science, technology and manufacturing. From the perspective of the transportation network, the Chengmianle Intercity railway has shortened the commuting time between the two places to within 1 hour, promoting the two-way flow of talents and technology. However, the data analysis shows that the economic subordination of Mianyang to Chengdu is as high as 72%, while the subordination of Chengdu to Mianyang is only 35%, indicating that this connection has a significant one-way dependence feature. Further investigation found that local enterprises in Mianyang are more inclined to move their research and development center to Chengdu, leading to the "siphon effect" intensified. This case reveals the two sides of the core city's radiation capacity: it can promote the development of surrounding cities in the short term, but it may inhibit the innovation capacity of secondary cities in the long term.

4.4 Analysis of the Direction of Economic Connections

The city with the largest economic affiliation degree to a certain city is the primary connection city, which represents the main direction of economic connection of that city. The economic affiliation degree model, that is, formula (8), is used to judge the main economic connection directions of each city in the Chengdu - Chongqing urban agglomeration. According to the calculated results, the economic connection directions of the Chengdu - Chongqing urban agglomeration have three directional characteristics: First, it points to the core cities of the urban agglomeration. The primary connection cities of most cities in the regional urban agglomerations of Sichuan Province are Chengdu, and the secondary connection cities of the remaining cities are also Chengdu. Second, it points to adjacent cities. The primary connection cities of some cities are the nearest adjacent cities, and the secondary connection cities of most cities are the nearest adjacent cities. Third, it points to regional central cities. The secondary connection cities of some cities are regional central cities, and the tertiary connection cities of some other cities are regional central cities.

Based on the calculation results of economic connection intensity and economic affiliation degree, the economic hinterland can be divided into three categories: the first is the core economic hinterland, the second is the competitive economic hinterland, and the third is the marginal economic hinterland. The core economic hinterland of Chengdu is the Chengdu Plain. The main economic connection direction of Chengdu still extends southward and northward along the Chengdu - Deyang - Mianyang - Leshan development axis. At the same time, there is a certain foundation for joint development in the southeast direction with Chongqing and Ziyang.

Overall, the urban agglomerations in Sichuan Province region is still in the initial development stage. The economic connections of most cities are relatively loose. The economic connections between Chengdu and the cities in the Chengdu Plain are relatively close. However, as the core of the urban agglomeration, Chengdu has insufficient driving effects on the numerous cities in the middle of the Sichuan Basin. Some cities in the southern Sichuan urban - intensive area and the

Nansui - Guang urban - intensive area have a higher degree of economic affiliation to Chongqing than to Chengdu. The internal economic connections in the Dawan urban - intensive area on the northeast edge of the Sichuan Basin are the weakest.

5. Conclusion

The overall spatial economic connection of the urban agglomerations in Sichuan Province region is relatively loose. The spatial economic connections between most cities within 90 kilometers of each other are weak.

The influence of Chengdu has broken through the Chengdu Plain and begun to extend to southern Sichuan and northeastern Sichuan. The spatial economic connection shows a radial pattern centered on Chengdu. However, the cities within the radiation area of Chengdu have only established a certain degree of spatial economic connection with Chengdu, and the economic exchanges among them are very weak, failing to form an integrated whole with close exchanges.

The cities in the Sichuan Province area basically only have economic connections within their respective provinces or municipalities. The cross - administrative - region economic exchanges are very weak, and the urban agglomerations in Sichuan Province region has not formed an integrated whole.

The economic connection directions of the urban agglomerations in Sichuan Province region have obvious directional characteristics. The main economic connection directions of the vast majority of cities point to the core cities, followed by adjacent cities, and finally to regional central cities.

The main economic connection direction of Chengdu is still the Chengdu - Deyang - Mianyang - Leshan development axis. At the same time, economic exchanges with Ziyang and Chongqing in the southeast direction have made progress.

The marginal areas of Sichuan Province have a relatively low intensity of economic connection due to their relatively long distance from Chengdu, the core city. Neijiang and Zigong in southern Sichuan have the potential for urban integration development. The economic connection directions of the Nansui - Guang urban - intensive area mostly point to the western Chongqing area.

Based on the above findings, this paper proposes the following policy recommendations:

1) Optimization of transportation network: Priority should be given to the construction of high-speed railways and expressways in the northeast and south Sichuan regions to shorten the time and space distance between the marginal cities and Chengdu.

2) Industrial division reconstruction: Through tax incentives and enclave economic model, we will guide the transfer of Chengdu's capital-intensive industries to Deyang and Meishan, and cultivate regional industrial chain clusters.

3) Pilot reform of administrative divisions: Set up an "economic cooperation demonstration zone" in the Chengdu-Chongqing border zone to explore cross-provincial tax sharing and joint investment mechanisms.

4) Data platform construction: Establish a dynamic monitoring system for economic ties in Sichuan city clusters, integrate traffic, population, and industry data, and provide real-time support for policy formulation.

The limitation of this study is that the lag effect of ecological constraints and policy interventions is not fully considered. In the future, system dynamics models can be combined to simulate the evolution path of economic linkages under different scenarios.

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