Research on Regional Innovation Capability Based on Grey Relation Analysis

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Abstract. Regional innovation ability evaluation is a powerful engine to promote high-quality economic development, and also an important part of the strategy of strengthening the province through innovation. In this paper, the regional innovation capacity evaluation index system is constructed from three dimensions of regional innovation input, regional innovation environment and regional innovation output. By using the grey correlation analysis method, the regional innovation capacity of 13 cities and states in Hubei Province in 2019 is evaluated and ranked. The results show that the regional innovation capacity of Hubei Province is roughly distributed in ladder shape. In this paper, 13 cities and prefectures in Hubei province are divided into three levels, and some suggestions are put forward to improve the overall ability of scientific and technological innovation and to balance the development of regional innovation in Hubei province.

1. Introduction

Foreign scholars realized the importance of regional innovation capability evaluation earlier, and carried out empirical research on different research objects with different research methods. Cooke et al. put forward the concept of regional innovation system for the first time in the 1990s. He regarded the innovation subjects such as enterprises, universities and research institutions with close geographical proximity and closes interrelation as regional innovation system, and took the regional innovation system asa policy tool to promote regional innovation development. Caroline [1] found through empirical research that the innovation ability of enterprises with greater influence in a region has a greater impact on the overall ability of scientific and technological innovation in the region.

In the past ten years, domestic scholars have paid continuous attention to and studied the influencing factors and evaluation methods of regional innovation capability. Hou Fenghua et al. [2] constructed a regional innovation capability evaluation index system covering 22 indexes, and evaluated and analyzed the scientific and technological innovation data of 10 provinces and cities in eastern China. Zhang Ling et al. [3] constructed an evaluation system with humanistic environment, service support and infrastructure as the firstlevel indicators. Zhang Yongan et al. [4] used the technology innovation theory to construct the PMC index model based on the policy text, and selected one policy at the national level, Beijing city level and Zhongguancun level for quantitative evaluation. Chen Haipeng et al. [5] used principal component analysis to rank the innovation ability of 17 cities in Shandong Province. Li Meijuan et al. [6] proposed a dynamic evaluation method based on grey target theory to evaluate and analyze the...
provincial collaborative innovation capability in China from 2009 to 2013. Ruan Rongbin et al. [7] constructed the evaluation index system of regional scientific and technological innovation ability in Fujian Province, which covers four aspects: the input level of regional scientific and technological innovation, the basic environment of regional scientific and technological innovation, the output level of regional scientific and technological innovation, and the scientific and technological innovation ability of regional enterprises. Song Shuaibang [8] used factor analysis method to investigate the regional innovation ability of China and all provincial regions from 2006 to 2017, and analyzed the overall situation and regional differences of China's regional innovation ability. To sum up, the academic circle has formed a batch of quality research results in the evaluation of regional innovation ability. However, in reality, if the sample data is not large enough or does not conform to a certain distribution, it is difficult to conduct in-depth analysis on the data. Grey correlation analysis does not require strict sample data, which can effectively make up for this defect. The main connotation is to analyze its development trend according to the proximity degree of the curve shape of the sequence of various factors.

2. Evaluation index system
On the basis of previous studies, combining with the actual regional innovation in Hubei Province and following the principles of comprehensiveness, scientificity, representativeness and availability of data, this paper constructs the evaluation index system of regional innovation ability in Hubei Province, which consists of 3 first-level indexes and 11 second-level indexes. See Table 1 for details:

| First level indicators | Second level indicators |
|------------------------|-------------------------|
| A Regional innovation input | X1 Number of research institutions/unit |
|                        | X2 Total number of researchers/person |
|                        | X3 Total expenditure on science and technology/million |
|                        | X4 Infrastructure construction cost/million |
|                        | X5 Research equipment assets/million |
| B Regional innovation environment | X6 Number of scientific research graduates / persons |
|                        | X7 Number of researchers with senior titles/persons |
|                        | X8 Scientific paper/paper |
| C Regional innovation output | X9 Number of patent applications accepted/piece |
|                        | X10 Revenue from science and technology /million |
|                        | X11 Revenue from production and operation /million |

Regional innovation input is the starting point of innovation-driven development process, regional innovation environment is the key dimension of regional innovation ability evaluation, and regional innovation output is the final embodiment of knowledge creation and transformation of scientific and technological achievements. This paper chooses from these three aspects to construct the regional innovation ability evaluation system in Hubei Province, which has a strong scientific nature and rationality.

3. Calculation of regional innovation capability

3.1 Collect data and construct sample matrix
In this paper, the scientific and technological innovation data of 13 cities and prefectures in Hubei Province in 2019 are obtained from the Hubei science and technology statistical yearbook 2019 and
Hubei statistical yearbook 2019, and 11 index data of 13 cities and prefectures form a sample matrix. Due to the limitation of space, the original data and sample matrix are no longer listed.

3.2 Conduct dimensionless treatment

The initial value method is used for dimensionless processing of the data in the following formula:

\[ y_{ij} = \frac{x_{ij}}{\sqrt[n]{\sum_{j=1}^{n} x_{ij}}} \]  

(1)

The following are the results of the processing of the 11 second-order indicators:

|   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.17 | 2.00 | 0.83 | 2.00 | 1.83 | 0.50 | 0.33 | 0.50 | 0.67 | 0.83 | 0.50 | 0.33 | 0.50 |
| 1.41 | 1.38 | 1.39 | 1.43 | 1.38 | 0.54 | 0.96 | 0.87 | 1.19 | 0.83 | 0.69 | 0.60 | 0.64 |
| 1.72 | 1.23 | 0.44 | 1.52 | 1.33 | 1.12 | 0.92 | 1.01 | 1.30 | 0.88 | 0.46 | 0.29 | 0.24 |
| 1.49 | 1.22 | 1.30 | 1.77 | 1.43 | 0.83 | 0.89 | 0.66 | 0.91 | 0.97 | 0.89 | 0.53 | 0.47 |
| 1.40 | 1.36 | 1.46 | 1.42 | 1.16 | 1.48 | 1.18 | 0.80 | 0.52 | 0.61 | 0.61 | 0.40 | 0.35 |
| 1.68 | 1.30 | 2.11 | 1.39 | 0.81 | 1.51 | 0.85 | 1.00 | 0.63 | 0.88 | 0.64 | 0.46 | 0.44 |
| 1.39 | 1.11 | 0.39 | 1.17 | 1.06 | 1.26 | 0.93 | 0.88 | 0.76 | 0.32 | 0.85 | 0.84 | 0.86 |
| 2.09 | 0.83 | 0.65 | 1.75 | 1.11 | 1.59 | 1.00 | 0.62 | 0.52 | 0.67 | 0.75 | 0.59 | 0.41 |
| 2.14 | 0.10 | 0.11 | 1.86 | 1.15 | 1.81 | 0.80 | 0.66 | 0.56 | 0.46 | 0.46 | 0.43 | 0.44 |
| 1.81 | 1.13 | 0.09 | 1.73 | 1.81 | 1.65 | 1.30 | 1.19 | 0.07 | 0.16 | 0.07 | 0.04 | 0.07 |
| 1.54 | 1.27 | 0.68 | 1.35 | 1.35 | 0.95 | 0.73 | 0.84 | 0.85 | 0.42 | 0.83 | 0.82 | 0.75 |

3.3 Determine reference sequence

Determine the reference sequence formula:

\[ Y_t = (y_{1t}, y_{2t} \cdots y_{mt})^T, \quad (t = 1,2, \ldots, n) \]  

(2)

3.4 Calculate the sequence difference and find the maximum and minimum values

One by one to calculate each index sequence and the absolute difference between the reference sequence corresponding element, from the calculation of the maximum number of find all the elements in the sequence difference: M=2.79, the minimumS=0.00.

3.5 Calculation of correlation coefficient

The correlation coefficient calculation formula is as follows:

\[ r_{ij} = \frac{s + \delta M}{s_{ij} + \delta M}, \quad \delta \in (0,1) \]  

(3)

Where \( \delta \) is the resolution coefficient, which is used to weaken the maximum M and is generally calculated by taking \( \delta =0.5 \). The calculation results of the correlation coefficient between the reference sequence and the comparison sequence are as follows:

|   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 0.89 | 0.51 | 0.89 | 0.81 | 0.45 | 0.43 | 0.45 | 0.48 | 0.51 | 0.45 | 0.43 | 0.45 |
| 0.98 | 0.97 | 0.79 | 1.00 | 0.96 | 0.61 | 0.74 | 0.71 | 0.85 | 0.70 | 0.65 | 0.63 | 0.64 |
| 1.00 | 0.74 | 0.66 | 0.88 | 0.78 | 0.70 | 0.64 | 0.66 | 0.77 | 0.62 | 0.52 | 0.49 | 0.48 |
| 0.83 | 0.72 | 0.63 | 1.00 | 0.81 | 0.60 | 0.61 | 0.56 | 0.62 | 0.63 | 0.61 | 0.53 | 0.52 |
| 0.95 | 0.92 | 0.86 | 0.95 | 0.82 | 0.76 | 1.00 | 0.82 | 0.67 | 0.59 | 0.62 | 0.56 | 0.55 |
| 1.00 | 0.78 | 0.90 | 0.83 | 0.62 | 0.59 | 0.89 | 0.63 | 0.67 | 0.57 | 0.57 | 0.53 | 0.53 |
| 1.00 | 0.83 | 0.75 | 0.86 | 0.81 | 0.74 | 0.91 | 0.75 | 0.73 | 0.68 | 0.72 | 0.72 | 0.72 |
| 1.00 | 0.52 | 0.51 | 0.80 | 0.58 | 0.55 | 0.73 | 0.56 | 0.49 | 0.47 | 0.51 | 0.48 | 0.45 |
| 1.00 | 0.55 | 0.52 | 0.83 | 0.58 | 0.52 | 0.81 | 0.51 | 0.34 | 0.47 | 0.45 | 0.45 | 0.45 |
| 0.99 | 0.67 | 0.58 | 0.94 | 1.00 | 0.73 | 0.90 | 0.73 | 0.69 | 0.44 | 0.44 | 0.44 | 0.44 |
| 1.00 | 0.84 | 0.67 | 0.88 | 0.88 | 0.67 | 0.70 | 0.63 | 0.66 | 0.67 | 0.66 | 0.66 | 0.64 |

3.6 Calculate the grey correlation degree and analyze the results

Correlation coefficient is the correlation degree value of different index sequence and reference sequence, which is not convenient for overall comparison. Therefore, it is necessary to calculate the
mean value of correlation coefficient of all indexes and reference sequence. The formula for calculating grey correlation degree is as follows:

\[ Z_j = \frac{1}{m} \sum_{i=1}^{m} r_{ij}, \quad (j = 1, 2, \ldots, n) \] (4)

The correlation coefficient of regional innovation capacity of 13 cities and prefectures in Hubei Province in 2019 is calculated as follows:

| City     | Coefficient | Ranking | City     | Coefficient | Ranking |
|----------|-------------|---------|----------|-------------|---------|
| Wuhan    | 0.9850      | 1       | Huangshi | 0.7214      | 4       |
| Shiyan   | 0.6795      | 6       | Yichang  | 0.8323      | 2       |
| Xiangyang| 0.7782      | 3       | Ezhou    | 0.6330      | 9       |
| Jingmen  | 0.6938      | 5       | Xiaogan  | 0.6666      | 7       |
| Jingzhou | 0.6331      | 8       | Huanggang| 0.5988      | 10      |
| Xianning | 0.5675      | 11      | Suizhou  | 0.5487      | 12      |
| Enshi    | 0.5281      | 13      |          |             |         |

It can be seen from the above table that in 2019, the regional innovation ability of the 13 cities and prefects in Hubei Province from strong to weak is: Wuhan, Yichang, Xiangyang, Huangshi, Jingmen, Shiyan, Xiaogan, Jingzhou, Ezhou, Huanggang, Xianning, Suizhou and Enshi.

4. Summary and Suggestions
The regional innovation ability of Hubei Province has obvious gradient difference on the whole, showing obvious pyramid stratification phenomenon, which can be divided into three levels on the whole. The first level is "one main two deputy": Wuhan City, Yichang City, Xiangyang. The second level is Huangshi City, Jingmen City, Shiyan City, Xiaogan City, Jingzhou City; the third level is Ezhou City, Huanggang City, Xianning City, Suizhou, Enshi. In order to promote the balanced development of regional innovation and enhance the overall ability of scientific and technological innovation in Hubei Province, this paper puts forward the following suggestions:

1) First-level regions need to give full play to their regional advantages and build a national high-level regional innovation highland. Wuhan, Yichang and Xiangyang are rich in scientific and educational personnel resources and have outstanding advantages in scientific and technological innovation. Hightech industries represented by "optical core screen terminal network" and biomedicine are developing at an accelerated pace.

2) The regions at the second level should give full play to their comparative advantages and increase investment in infrastructure construction and science and technology. Huangshi, Jingmen, Shiyan, Xiaogan, Jingzhou and other cities and prefectures should give full play to the leading role of the government and the roleof enterprises as the main body combine with their own natural endowment of regional innovation, accelerate the cultivation and aggregation of scitech innovation industrial clusters with scale effect.

3) The third level of regions needs to give play to the advantages of backwardness and cultivate the core competitiveness of regional scientific and technological innovation. We need to step up the development of information and transportation infrastructure, increase the popularity of the Internet and mobile communications, use network platforms as the carrier and regional central cities as the radiating
points of innovation, and boost the innovation capacity and economic development level of surrounding areas.

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