Measurement and Analysis of Manufacturing Industry Agglomeration in Wuhan Based on the Big Data Analysis Method

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Abstract. As an important carrier of urban and regional development, the process of formation, agglomeration and diffusion of manufacturing industry agglomeration directly affects the operational efficiency of socio-economic factors and the regional spatial pattern. In this paper, the manufacturing industry agglomeration degree of Wuhan City from 2015–2019 is measured in terms of total industrial output value and number of employees using the big data analysis method. Based on the analysis results of the big data, the problems of manufacturing industry agglomeration development in Wuhan City are analyzed and suggestions are made in this regard.

Keywords: Big Data Analysis · Location Entropy Index · Wuhan Manufacturing Industry · Industrial Agglomeration

1 Introduction

Manufacturing industry is the main body of China's real economy, and the development level of manufacturing industry is a direct reflection of the country's high productivity and the guarantee of national economic development. As a pilot city of "Made in China 2025", Wuhan is in the middle and late industrialization accelerating stage, and the manufacturing industry has greater development potential. The national implementation of "Made in China 2025", "Yangtze River Economic Belt" and other major strategies to promote the construction of the city cluster in the middle reaches of the Yangtze River has injected new momentum into the development of Wuhan's manufacturing industry. Since the implementation of the "Doubling Plan" for industrial development in Wuhan in 2011, the scale of Wuhan's manufacturing industry has continued to grow, its competitiveness has been significantly enhanced, some fields are at the world's leading level, and its comprehensive strength has continued to rise. 2019 Wuhan's total industrial output value above the scale is 147.9842 billion yuan, and the industrial added value is 410.145 billion yuan, an increase of 6.5%. The annual operating income of industrial enterprises above the scale was 1,417.843 billion yuan, an increase of 1.7%.

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2 Literature Review

Industrial agglomeration, as a regional economic development model, is a process when the same or similar enterprises are highly concentrated in a specific area and various capital elements gradually converge in that specific area. In the regional economic development where the competition for talents, capital and technology is becoming increasingly fierce, using the agglomeration effect to strengthen economies of scale is an important idea to promote regional development.

Marshall Explained the concept of industrial agglomeration in detail in his work "Principles of Economics", which pioneered the study of industrial agglomeration theory [6]. Fujita M et al. argue that the source of benefits of industrial agglomeration is the economy of scale, and the process of increasing returns to scale of enterprises, transportation costs and the flow of production factors generate interactions and accumulate in a continuous cycle leading to the creation of industrial agglomeration [2]. Porter analyzed industrial agglomeration from the perspective of industrial chains, and found that when upstream and downstream industries gather, it is more beneficial to share production factors [7].

In terms of industry, many domestic scholars have studied the impact of manufacturing industry agglomeration effect on regional economy. Wei Shouhua et al. found that the agglomeration of manufacturing sub-centers and its interactive effect with productive services significantly increased urban productivity [9]. Du Shuang et al. pointed out that industrial agglomeration and market concentration are important factors affecting regional innovation capacity [1]. Both manufacturing agglomeration and market concentration in the Beijing-Tianjin-Hebei and Yangtze River Delta economic zones have contributed to regional innovation capacity to some extent. Yang, Renfa et al. found through empirical analysis that manufacturing agglomeration can significantly promote high-quality development in the Yangtze River Economic Zone [10].

3 Wuhan Manufacturing Industry Agglomeration Measurement Based on Big Data Analysis

3.1 Method Selection and Data Selection

This paper uses the location entropy index to calculate the manufacturing industry agglomeration degree in Wuhan and analyze the industry variability of manufacturing agglomeration level in Wuhan. The location entropy index, also called regional concentration of production or specialization rate, was proposed by P. Haggett to reflect the degree of concentration of an industry in a certain region and to measure the spatial distribution of the industry. When the location entropy is greater than 1, the industry is considered to be a specialized sector in the region with comparative advantage and agglomeration capacity; conversely, it is lower than the national average. Its calculation formula is as follows.

$$LQ_{ij} = \frac{q_{ij}/q_j}{Q_i/Q} \tag{1}$$

Where LQ_{ij} represents the location entropy index of industry i in region j. q_j represents industry-related indexes (such as output value, number of employees, etc.) of industry i in region j. q_j represents all industry-related indicators in region j. Q_i represents industry i-related indicators in the whole country. Q represents all industry-related indicators in the country.

The location entropy index can adequately compare the development level of individual industries in a certain region with the national average development level, and clarify the level and position of industrial agglomeration in the region in the country, but the index has the limitation of not being able to avoid factors such as differences in the scale of different industries themselves and the number of enterprises. On the whole, the degree of influence is negligible due to the relatively large number of enterprises, so location entropy is still a relatively accurate measure of industry agglomeration level better. In view of the availability of data, this paper will calculate the location entropy of 31 sub-industries of Wuhan manufacturing industry in terms of both total industrial output value and number of employees. The data of total industrial output value and the number of employees in Wuhan and the whole country are obtained from the China Statistical Yearbook and Wuhan Statistical Yearbook of each year, respectively.

3.2 Big Data Analysis

3.2.1 Regional Entropy Index of Gross Industrial Output Value

Using Eq. (1), the location entropy index of the gross industrial output value of the manufacturing industry in Wuhan is calculated. q_{ij} The gross industrial output value of each manufacturing industry segment in Wuhan City is selected. q_j The gross national product of Wuhan city is selected. Q_i The total industrial output value of each manufacturing industry in the country is selected. Q The national gross national product is selected. The results are shown in Table 1.

From the overall perspective, the location entropy index of manufacturing industry in Wuhan is less than 1 from 2015 to 2019, but the overall increase of location entropy index of manufacturing industry in 5 years. It indicates that although the manufacturing industry in Wuhan does not yet have a locational advantage in the country from the index of total industrial output value, the development of manufacturing industry in Wuhan has gradually improved in recent years, the degree of agglomeration has increased, and industrial clusters have taken shape.

Looking at the subdivided industries of manufacturing industry, the location entropy index increased in 21 industries and decreased in 10 industries among 31 major categories. Only three subdivided industries, namely, tobacco products, automobile manufacturing, metal products, machinery and equipment repair, have a location entropy index greater than 1 in five years, and have the advantage of industrial agglomeration in the country. In particular, the tobacco products industry has a location entropy index greater than 4, which is more than double that of the second-ranked automobile manufacturing industry. The larger the location entropy value, the higher the degree of agglomeration, highlighting the industrial agglomeration advantage of tobacco products industry in Wuhan. The computer, communication and other electronic equipment manufacturing industry saw a decrease in the index in 2018 and 2019, slightly less than 1.

Table 1. Wuhan manufacturing industry 2015–2019 regional entropy index of gross industrial output value

Type of manufacturing	2015	2016	2017	2018	2019	Average value	Sort by
Tobacco products	4.37	4.50	4.68	4.00	3.97	4.31	1
Automotive	2.22	2.13	2.37	2.22	2.26	2.24	2
Metal products, machinery	2.73	1.00	1.26	1.50	1.45	1.59	3
Computer, communication	1.04	1.19	1.02	0.95	0.92	1.02	4
Ferrous metal smelting	0.69	0.95	1.18	1.12	0.96	0.98	5
Comprehensive utilization of waste resources	0.67	0.80	0.99	1.27	0.75	0.90	6
Electrical machinery	0.86	0.75	0.85	0.96	0.92	0.87	7
Printing and recording media reproduction	0.20	0.72	0.98	1.04	1.00	0.79	8
Metal products	0.64	0.67	0.85	0.84	0.90	0.78	9
Pharmaceutical	0.56	0.70	0.84	1.10	0.63	0.77	10
Wine, beverages and refined tea	0.82	0.64	0.68	0.54	0.64	0.67	11
Railroad, ship, aerospace	0.51	0.50	0.69	0.98	0.53	0.64	12
Specialized equipment	0.53	0.60	0.60	0.67	0.77	0.63	13
Other Manufacturing	1.99	0.36	0.23	0.21	0.16	0.59	14
Food Manufacturing	0.41	0.48	0.58	0.67	0.74	0.58	15
Rubber and plastic products industry	0.58	0.47	0.52	0.65	0.57	0.56	16
Instrument manufacturing	0.54	0.39	0.40	0.54	0.75	0.52	17
Paper and paper products industry	0.45	0.43	0.48	0.49	0.57	0.48	18
Non-metallic mineral products	0.35	0.33	0.49	0.57	0.59	0.46	19
Petroleum processing, coking and nuclear fuel	0.63	0.52	0.58	0.56	0.03	0.46	20
Agri-food processing	0.43	0.35	0.42	0.48	0.49	0.44	21
General Equipment	0.47	0.35	0.35	0.37	0.41	0.39	22
Textile and apparel	0.29	0.25	0.34	0.47	0.57	0.38	23

(*continued*)

Table 1. (*continued*)

Type of manufacturing	2015	2016	2017	2018	2019	Average value	Sort by
Education, industry, sports	0.50	0.17	0.32	0.38	0.43	0.36	24
Chemical raw materials	0.27	0.23	0.30	0.32	0.63	0.35	25
Textile industry	0.17	0.15	0.19	0.27	0.22	0.20	26
Wood processing and wood, bamboo, rattan, palm	0.12	0.11	0.14	0.25	0.21	0.16	27
Furniture Manufacturing	0.11	0.09	0.11	0.12	0.17	0.12	28
Leather, fur, feathers and their products	0.07	0.06	0.05	0.08	0.10	0.07	29
Non-ferrous metal smelting	0.07	0.06	0.07	0.04	0.04	0.05	30
Chemical fiber manufacturing	0.03	0.02	0.03	0.02	0.02	0.03	31
Total	0.67	0.67	0.77	0.80	0.79	0.74	–

3.2.2 Entropy Index of the Number of Employees

The location entropy index of the number of employees in the manufacturing industry in Wuhan is calculated using Eq. (1). q_{ij} The annual average number of all employees in each manufacturing industry segment in Wuhan City is selected. q_j The number of people employed in Wuhan is selected. Q_i The average number of employees in each manufacturing industry in China is selected. Q The number of employed persons in the country is selected. The results are shown in Table 2 after the calculation of data collation.

From an overall perspective, the location entropy index of manufacturing industry in Wuhan has decreased from 2015 to 2019, but the decrease is small, and the location entropy index is still all greater than 1. This indicates that from the index of the number of employees, the manufacturing industry in Wuhan has a strong agglomeration ability relative to the country, and has a strong driving effect on the regional economy.

The location entropy indexes of 20 of the 31 sub-sectors decreased, 9 increased, and 2 remained basically unchanged. Tobacco products industry, metal products, machinery and equipment repair industry, automobile manufacturing, ferrous metal smelting and rolling processing industry, pharmaceutical manufacturing, comprehensive utilization of waste resources, instrumentation manufacturing, computer, communication and other electronic equipment manufacturing, printing and recording media reproduction, electrical machinery and equipment manufacturing, railroad, ship, aerospace and other transportation equipment manufacturing, metal products industry, wine The location entropy index of 14 industries, including wine, beverage and refined tea and food manufacturing, is greater than 1 in 5 years, and there are 10 sub-sectors higher than the

Table 2. Wuhan manufacturing industry 2015–2019 location entropy index of the number of employees

Type of manufacturing	2015	2016	2017	2018	2019	Average value	Sort by
Tobacco	4.22	4.14	4.82	5.25	5.14	4.72	1
Metal products, machinery and equipment repair	4.51	4.55	4.27	3.46	3.67	4.09	2
Automotive Manufacturing	3.47	3.60	3.81	3.70	3.24	3.56	3
Ferrous metal smelting and rolling processing	3.17	2.68	2.32	2.18	1.52	2.38	4
Pharmaceutical Manufacturing	2.00	2.09	2.26	2.44	1.62	2.08	5
Comprehensive utilization of waste resources industry	2.79	2.24	1.74	1.89	1.68	2.07	6
Instrument manufacturing	1.57	1.51	1.38	1.62	1.80	1.58	7
Computer, communications	1.71	1.77	1.42	1.51	1.46	1.57	8
Printing and recording media reproduction	1.33	1.21	1.47	1.52	1.42	1.39	9
Electrical machinery	1.40	1.42	1.31	1.34	1.26	1.35	10
Railroad, ship, aerospace	1.47	1.43	1.18	1.52	1.10	1.34	11
Specialized equipment	1.49	1.47	1.39	1.35	0.95	1.33	12
Metal products industry	1.34	1.27	1.35	1.20	1.08	1.25	13
Wine, beverages and refined tea	1.27	1.25	1.19	1.13	1.18	1.20	14
Food Manufacturing	1.06	1.07	1.07	1.03	1.06	1.06	15
General Equipment Manufacturing	1.02	0.96	0.83	0.78	0.72	0.86	16
Agri-food processing	0.70	0.66	0.73	0.79	0.80	0.74	17
Non-metallic mineral products	0.72	0.69	0.70	0.76	0.76	0.72	18
Rubber and plastic products	0.74	0.66	0.72	0.72	0.65	0.70	19
Paper and paper products	0.72	0.73	0.66	0.67	0.60	0.68	20

(*continued*)

Table 2. (*continued*)

Type of manufacturing	2015	2016	2017	2018	2019	Average value	Sort by
Textile and apparel industry	0.54	0.51	0.57	0.58	0.61	0.56	21
Petroleum processing, coking and nuclear fuel processing industry	0.64	0.63	0.65	0.59	0.12	0.53	22
Chemical raw materials and chemical products	0.47	0.42	0.45	0.47	0.59	0.48	23
Other Manufacturing	0.33	0.41	0.49	0.34	0.21	0.35	24
Textile industry	0.36	0.30	0.33	0.35	0.30	0.33	25
Wood processing and wood, bamboo, rattan, palm	0.27	0.23	0.30	0.36	0.38	0.31	26
Furniture Manufacturing	0.28	0.24	0.27	0.24	0.22	0.25	27
Education, industry, sports and recreational goods	0.18	0.18	0.19	0.23	0.25	0.21	28
Non-ferrous metal smelting and rolling processing	0.24	0.20	0.15	0.13	0.10	0.16	29
Chemical fiber manufacturing	0.06	0.06	0.06	0.06	0.06	0.06	30
Leather, fur, feathers and their products	0.05	0.05	0.04	0.04	0.04	0.04	31
Total	1.19	1.17	1.14	1.17	1.05	1.15	–

overall manufacturing industry. Among them, the highest location entropy index is the tobacco products industry, whose location entropy index reached the highest value of 5.25 in 2018, and these industries have high agglomeration effect and location advantages nationwide.

3.2.3 Combined Comparison of Two Indices

Referring to Huang Xianhai's criteria for the division of manufacturing industries by factor intensity [3], the 31 sub-industries of Wuhan manufacturing industry are divided into three major categories: labor-intensive, capital-intensive and technology-intensive, and the results are shown in Table 3.

According to Table 3, the location entropy indexes of total industrial output value and number of employees show that Wuhan has the highest concentration level of labor-intensive industries in the tobacco products industry, a higher concentration level in capital-intensive industries in the ferrous metal smelting and rolling processing industry,

Table 3. Industry Classification by Factor Intensity

Density of elements	Industry Type
Labor-intensive	Agricultural and sideline food processing; food manufacturing; wine, beverages and refined tea; tobacco products industry; textile industry; textile clothing, apparel industry; leather, fur, feathers and their products and footwear industry; wood processing and wood bamboo, rattan, palm, grass products industry
Capital-intensive	Furniture manufacturing; paper and paper products industry; printing and recording media reproduction industry; education, industrial arts, sports and recreational goods manufacturing; petroleum processing, coking and nuclear fuel processing industry; chemical fiber manufacturing; rubber and plastic products industry; non-metallic mineral products industry; ferrous metal smelting and rolling processing industry; non-ferrous metal smelting and rolling processing industry; metal products industry
Technology-intensive	Chemical raw materials and chemical products manufacturing; pharmaceutical manufacturing; general equipment manufacturing; special equipment manufacturing; automotive manufacturing; railroad, ship, aerospace and other transportation equipment manufacturing; electrical machinery and equipment manufacturing; computer, communications and other electronic equipment manufacturing; instrumentation manufacturing; other manufacturing; comprehensive utilization of waste resources industry; metal products, machinery and equipment repair industry

and a high concentration level in technology-intensive industries in the automobile manufacturing, computer, communication and other electronic equipment manufacturing, and metal products, machinery and equipment repair industries.

The results of categorizing and averaging the Wuhan manufacturing location entropy index according to labor-intensive, capital-intensive and technology-intensive are shown in Table 4.

Table 4 shows that the average value of agglomeration water of technology-intensive industries is the largest among the major categories of manufacturing industries in Wuhan, followed by the level of agglomeration of labor-intensive industries, and the smallest is the average value of agglomeration of capital-intensive industries. This indicates that Wuhan City is mainly developing high technology content manufacturing industry, and the traditional labor-intensive manufacturing industry is the second. However, it can be seen from the time dimension that the agglomeration level of technology-intensive industries shows a decreasing trend with a large decline. And the traditional manufacturing industry in general shows an upward trend and is more stable.

From the combination of total industrial output value and location entropy index of the number of employees, it is obvious that Wuhan has the advantage of agglomeration of manufacturing industry employees. Compared with the location entropy index of total industrial output value, there are as many as 15 industries with the average value

Table 4. Wuhan City Manufacturing Industry Cluster Level

Indicators	Density of elements	2015	2016	2017	2018	2019	Average value
Industrial output value of regional entropy	Labor-intensive	0.84	0.82	0.89	0.85	0.87	0.85
	Capital-intensive	0.39	0.40	0.51	0.53	0.48	0.46
	Technology-intensive	1.03	0.75	0.82	0.92	0.85	0.88
Number of employees Zone entropy	Labor-intensive	1.06	1.03	1.13	1.19	1.19	1.12
	Capital-intensive	0.86	0.78	0.78	0.75	0.62	0.76
	Technology-intensive	2.02	1.99	1.87	1.86	1.66	1.88

of location entropy index of the number of employees greater than 1. Among them, five industries, namely, tobacco products, automobile manufacturing, metal products, machinery and equipment repair, and computer, communication and other electronic equipment manufacturing, belong to the overlapping industries with mean value greater than 1. This shows that Wuhan manufacturing industry cluster is not only a specific type of industry, but a relatively balanced distribution.

4 Research Recommendations

4.1 Increase Training of Manufacturing Talents

High technology-intensive industries have high requirements for technical talents, and in order to form high-quality industrial clusters, Wuhan's manufacturing industry needs to establish a talent introduction and cultivation mechanism, pay attention to the development of innovative and professional talents, and formulate policies for attracting and retaining talents in a graded and classified manner [8]. We should improve the training system for highly skilled talents based on enterprises and vocational colleges, combining school education and enterprise training, and encourage college graduates to stay in Wuhan for entrepreneurship and employment.

4.2 Strengthen Transformation of Scientific and Technological Achievements

Aiming at the major strategic needs of the country and the high points of future industrial development, we will dovetail with the key areas of "Made in China 2025" and realize the transformation from "Made in Wuhan" to "Created in Wuhan". Combined with the actual manufacturing industry in Wuhan, make full use of the advantages of science and education resources in Wuhan, deepen the development mode of cooperation between industry, academia and research [5], provide a wider range of science and technology project resources for the development of Wuhan area.

4.3 Focus on Creating Industrial Clusters

To take the new industrialization path, revitalize the old industrial base of Wuhan and develop world-class manufacturing industry clusters, Wuhan needs to rely on the Wuhan city circle to eliminate surplus industries and transfer general manufacturing industries, integrate the advantages of existing industries and resource elements, and find the combination of industrial value chain and urban value chain according to local conditions [4]. Gather more enterprises to do a good job of supporting products related to large enterprises and large projects, and promote the improvement and upgrading of the industrial chain in the agglomeration area.

5 Conclusion

Development of manufacturing industry agglomeration in Wuhan City should based on the facts of Wuhan economy, and put into effect from aspects of increasing training of manufacturing talents, atrengthing transformation of scientific and technological achievement, and focusing on creating industrial clusters.

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