ISSN 2616-7433 Vol. 6, Issue 6: 86-94, DOI: 10.25236/FSST.2024.060614

Research on innovation output and characteristics of industry-university-research cooperation in artificial intelligence technology in Chinese provinces

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Abstract: *By analyzing the patent applications of artificial intelligence technology inventions in 31 provinces and cities in China from 2012 to 2021, this paper discusses the characteristics of artificial intelligence technology innovation output, and uses the time series analysis method to conduct research to accurately describe the current situation of China's artificial intelligence technology innovation output, and provides scientific decision support for the development of artificial intelligence technology in China. Through the analysis of the innovation output and network characteristics of AI technology cooperation, it is found that the innovation output of AI technology in China is increasing in absolute and relative differences. About a quarter of provinces have patent cooperation below the average; Finally, based on the analysis results, from the perspectives of innovation subjects and innovation networks, this paper proposes countermeasures and suggestions to improve the output level of artificial intelligence technology innovation and promote the coordinated development of industry, university and research.*

Keywords: *Industry-university-research cooperation; Artificial intelligence; Invention patent; Innovation network*

1. Introduction and literature review

In the context of the current change of science and technology industry, the strategic technology of artificial intelligence has become increasingly prominent. As an effective mode of technological innovation, industry-university-research cooperation can promote resource sharing and technological exchange among enterprises, research institutes and universities, and accelerate the transformation and application of scientific and technological achievements. Especially in the field of artificial intelligence, technological breakthroughs and innovations can be achieved through industry-university-research cooperation, and the competitiveness and innovation of the entire industry can be enhanced.

From the perspective of innovation output of industry-university-research cooperation, it can promote the innovation and application of artificial intelligence technology. Min Chao (2023) believes that in the process of cooperation, diversified partners can bring new technologies and complementary resources to enterprises and enhance their problem-solving ability[1]. It is helpful to integrate the resource advantages of enterprises, universities, and research institutes, and realize knowledge sharing and technology transfer. At the same time, it can also train more talents with innovative ability and practical experience to provide support for the development of the field of artificial intelligence.

From the perspective of network characteristics, AI technology industry-university-research cooperative innovation network has a complex structure and dynamic evolution process. Maggioni et al. (2006)established knowledge transfer networks to explore the characteristics of complex knowledge diffusion and aggregation among countries and regions through network characteristics[2]. The network is composed of multiple entities, including enterprises, universities, research institutes, etc. Zander (2014) explored the characteristics of knowledge flow and its influencing factors by constructing technical cooperation network[3]. Xu Xiaoyi (2015) built inter-disciplinary knowledge flow relationship network based on collaborative papers, and studied the relationship between inter-disciplinary knowledge flow from two aspects: the overall characteristics and nodes of the network[4]. Liu Fengchao (2011) analyzed the collaborative innovation network and evolution between "985" university and other universities, enterprises and research institutions[5]. Liu Qiong (2016) analyzed the evolution process of the innovation collaboration network with Tsinghua University as the central node, and found that different collaboration models have different outputs.[6]

Through research, scholars discussed the driving force and importance of industry-university-

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research cooperation innovation in artificial intelligence technology. They emphasized the role of policy incentives and industry-university-research collaboration in promoting innovation, as well as the importance of cooperation models and resource complementarity among all parties in technology R&D and innovation. In addition, some scholars also in-depth analyzed the internal mechanism of information flow, knowledge sharing and innovation output in the cooperation network, and used patent data to analyze the network characteristics formed by specific industries or universities to analyze the changes in their output or cooperation mode.

2. Data and materials

2.1 Index selection

In this paper, the number of artificial intelligence technology industry-university-research cooperation invention patents from 31 provinces and cities in China (excluding Hong Kong, Macao and Taiwan) from 2012 to 2021 is selected as the sample, and the data comes from the incoPat patent database, which covers massive patent information worldwide and supports various types of retrieval such as patent technology information, relevant persons and applicants. It has become a reliable source of patent data collation for large companies and academic institutions at home and abroad.

China has three types of patent applications: invention patent, utility model and design, and invention patent has the highest innovation and technical content. Therefore, this paper analyzes the number of invention patent applications in 31 provinces and cities in China with an application period from 2012 to 2021. The patents mentioned below are all patent applications for artificial intelligence technology inventions.

2.2 Data acquisition and processing

2.2.1 Data acquisition

In order to obtain the patent data consistent with the research in this paper, the search keywords refer to Wang Yawei's 13 core technology fields of artificial intelligence. The specific search method is shown in Appendix. The search time will be up to December 31, 2021, and a total of 18,837 data of invention patents in the field of artificial intelligence in China will be obtained.

2.2.2 Data processing

After excluding individual and overseas patents and selecting cooperative patents with the number of applicants greater than or equal to 2, 5,483 industry-university-research cooperative invention patents were obtained. With the applicant province and province as the province's patents, the time and spatial characteristics of artificial intelligence technology industry-university-research innovation output were studied. The address of each enterprise, university and research institute is taken as the address of patent application, reflecting the main space of innovation and revealing the current situation of the industry-university-research innovation network.

2.3 Research methods

2.3.1 Literature analysis

Collect and sort out theoretical viewpoints in the field of industry-university-research cooperation and patent cooperation network related to artificial intelligence, and sort out existing theoretical achievements. Analyze the shortcomings and gaps of the current research, so as to clarify the core issues and values of this study.

2.3.2 Time series analysis

Two indicators, range and standard deviation, are used to describe the absolute difference between different years. At the same time, coefficient of variation and Gini coefficient of location are used to reveal the relative difference, and then accurately depict the gap in the output level of artificial intelligence technology innovation.

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3. Descriptive statistical analysis of the output of industry-university-research cooperation innovation in artificial intelligence technology

3.1 Patent applications

Figure 1 shows the trend of artificial intelligence patent applications in China from 2012 to 2021. Both the total number of invention patents and the number of cooperative invention patents show an upward trend, reflecting the continuous enhancement of China's innovation ability in the field of artificial intelligence and the deepening of industry-university-research cooperation in the field of artificial intelligence, indicating that artificial intelligence technology will continue to expand in the future. This will help accelerate the innovation and application of artificial intelligence technology, and also provide new impetus for China's economic and social development.

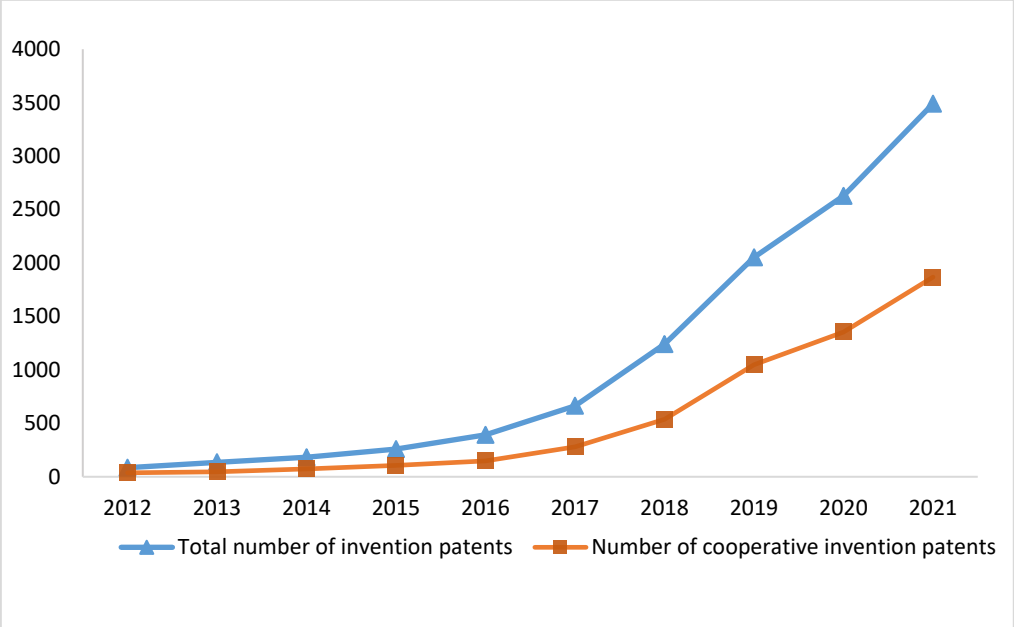

Figure 1: Patent applications for artificial intelligence inventions in China

3.2 Analysis of patent cooperation degree

Based on the ratio of the number of cooperative invention patents to the number of invention patents, the patent cooperation degree of artificial intelligence technology patents in various provinces and cities in China from 2012 to 2021 is calculated, as shown in Table 1.

As can be seen from Table 1, Beijing, Guangdong, Jiangsu and Zhejiang are all in the forefront, achieving a "double high" trend. The development of AI technology in these four provinces is relatively good. The number of invention patents and the number of cooperative invention patents in Qinghai are less than 10, indicating that AI technology in these provinces is starting to develop. In terms of the degree of patent cooperation, the degree of patent cooperation in Shanxi, Xizang, Guizhou and Liaoning is basically the same as the national level of 49.39%, and the degree of patent cooperation in 8 provinces and cities is less than the average level. Second, Qinghai and Heilongjiang's patent cooperation was higher than 80 percent, reflecting the lack of scientific research capacity in these provinces. Therefore, in order to ensure the rationalization of the degree of patent cooperation, the number of cooperative patents should be increased while ensuring that the number of patents reaches a certain standard, and the degree of patent cooperation should be maintained at a reasonable level.

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Table 1: Patent cooperation degree of provinces and cities in China

Rankings	Provinces	Number of invention patents	Number of co-invention patents	Degree of patent cooperation
1	Qinghai	8	7	87.50%
2	Amur	55	46	83.64%
3	Gansu	43	33	76.74%
4	Fujian	117	91	74.36%
5	Hunan	120	86	71.67%
6	Jiangxi	38	27	71.05%
7	Inner Mongolia	40	28	70.00%
8	Ningxia	19	13	68.42%
9	Tianjin	189	129	68.25%
10	Autonomous Region	34	23	67.65%
11	Henan (Province)	139	91	65.47%
12	Shandong	522	327	62.64%
13	Shanghai	543	328	60.41%
14	Guangxi	74	43	58.11%
15	Hubei	294	169	57.48%
16	Shaanxi	223	122	54.71%
17	Hebei	150	82	54.67%
18	Chungking	202	107	52.97%
19	Pekin	2640	1364	51.67%
20	Jiangsu	1162	598	51.46%
21	Szechuan	380	194	51.05%
22	Shanxi	36	18	50.00%
23	Xizang	4	2	50.00%
24	Guizhou	53	26	49.06%
25	Liaoning	257	125	48.64%
26	Canton	1659	797	48.04%
27	Ji Lin	69	31	44.93%
28	Anhui	288	127	44.10%
29	Hainan	29	11	37.93%
30	Yunnan	88	24	27.27%
31	Zhejiang	1626	418	25.71%
Total		11101	5483	49.39%

3.3 Provincial distribution of cooperative patents

ArcGIS software was used to draw the distribution of artificial intelligence technology industry-university-research cooperation patents in 2012, 2015, 2018 and 2021. The darker the color, the more patents, as shown in Figure 2.

a)year 2012

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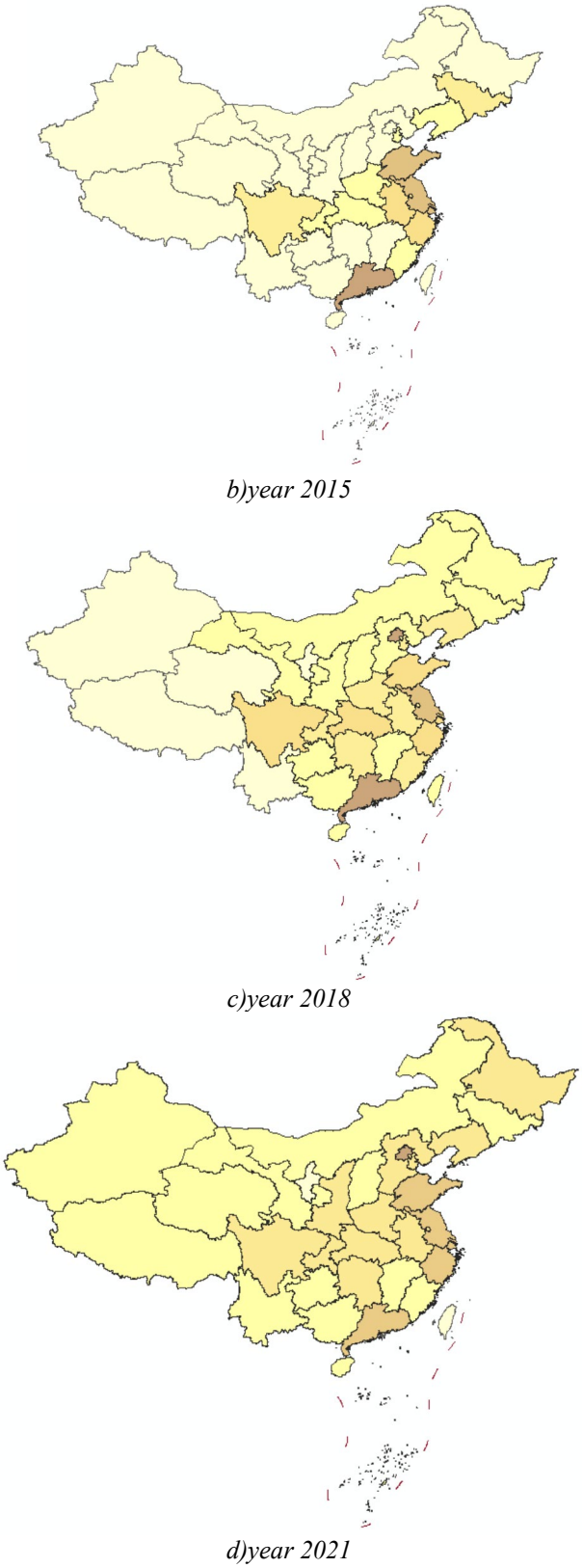

b)year 2015

c)year 2018

d)year 2021

Figure 2: Distribution of industry-university-research patents for artificial intelligence technology in China from 2012 to 2021

Judging from the evolution of patent cooperation from 2012 to 2021, Beijing, Jiangsu, Guangdong, Zhejiang and other provinces and cities take the lead in the development of AI industry, and exert influence on and lead the surrounding regions. The number of patents in the central and eastern regions is more prominent, and the western region has gradually joined in the cooperative innovation of AI

ISSN 2616-7433 Vol. 6, Issue 6: 86-94, DOI: 10.25236/FSST.2024.060614

technology. On the whole, the eastern region has made full use of the output of AI technology innovation to drive economic development. The low output of AI technology innovation in western and central regions reflects that provinces and cities with similar innovation capabilities have the characteristics of agglomeration, which is easy to drive the innovation and development of surrounding industrial, university and research institutions. Even if there is a need for cooperation in remote areas, it is easy to be limited. However, with the continuous development of artificial intelligence technology and the construction of an innovative country, many provinces have the cooperation patents of artificial intelligence technology, which indicates the pulling role of strategic drive on artificial intelligence and economy.

4. Analysis of the time sequence characteristics of artificial intelligence technology industry-university-research cooperation innovation output

4.1 Absolute difference analysis

4.1.1 Absolute difference measurement

This paper selects range and standard deviation to describe the absolute difference of innovation output of industry-university-research cooperation in artificial intelligence technology in China, and analyzes it. The formula for calculating the standard deviation is:

$$Std = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N} (x_i - \overline{x})^2} \quad (1)$$

Std represents standard deviation, x_i represents the number of artificial intelligence invention patents in the i province, city, and district;$\overline{x}$ is the average value of invention patents; n is the total number of provinces and cities.

4.1.2 Result analysis

Based on the number of artificial intelligence technology industry-university-research cooperation patents in 31 provinces and cities in China from 2012 to 2021, the range and standard deviation of artificial intelligence technology innovation output are calculated, as shown in Figure 3.

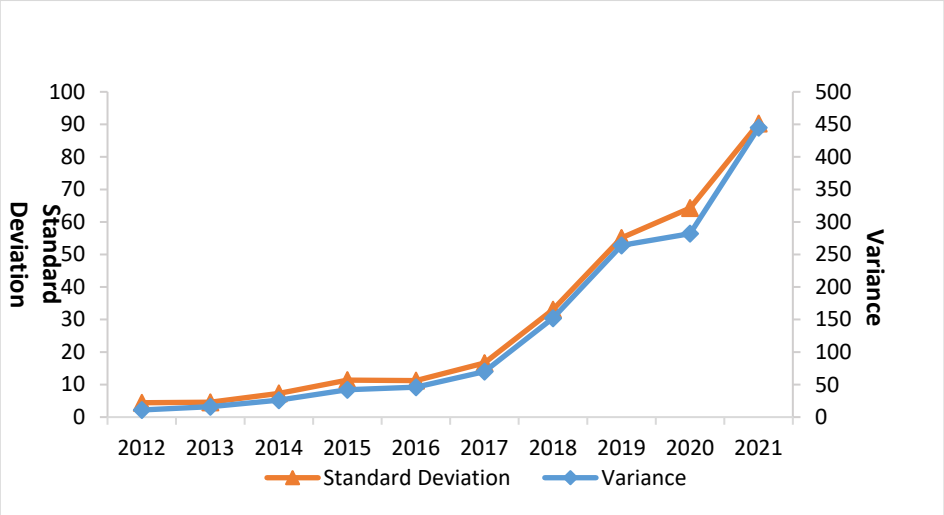

Figure 3: Change of absolute difference of AI technology innovation output from 2012 to 2021

Figure 3 shows that the absolute difference from 2012 to 2021 increases with time, and the absolute quantity of national innovation output presents an unbalanced situation. Before 2017, the unbalanced situation of innovation output grew slowly, while after 2017, the unbalanced situation of innovation output grew rapidly. It is confirmed that since 2017, the state has supported the development of artificial intelligence industry in different regions to bring different impacts, although China's artificial intelligence invention patent applications have increased year by year, but there is still a gap between the absolute growth of innovation output in China, 2012-2021, the difference grew from 11 to 445, the growth rate is 39.45. The standard deviation increased from 4.42 to 90.3, with a growth rate of 19.43. The data show that the increase of range and standard deviation reflects that the innovation output and absolute

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difference of China's artificial intelligence industry are increasing year by year to some extent, and there is an imbalance in the development of artificial intelligence technology among provinces.

4.2 Analysis of relative differences

4.2.1 Relative difference measurement

Coefficient of variation and Gini coefficient of location are used to measure the relative difference. The formula is:

$$CV = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}/\overline{x} \tag{2}$$

$$G = 1 - \frac{1}{N}(2\sum_{i=1}^{n-1} W_I + 1) \tag{3}$$

CV represents the coefficient of variation; G location Gini coefficient; W_I represents the proportion of the number of patents accumulated from Group 1 to Group **i** to the national number; x_i represents the number of artificial intelligence invention patents in the $i$province, city and district; $\overline{x}$ is the average value of invention patents; n is the total number of provinces and cities.

4.2.2 Result analysis

Based on the number of artificial intelligence technology industry-university-research cooperation patents in 31 provinces and cities in China during 2012-2021, the locational Gini coefficient and coefficient of variation of artificial intelligence technology innovation output during 2012-2021 were calculated, as shown in Figure 4.

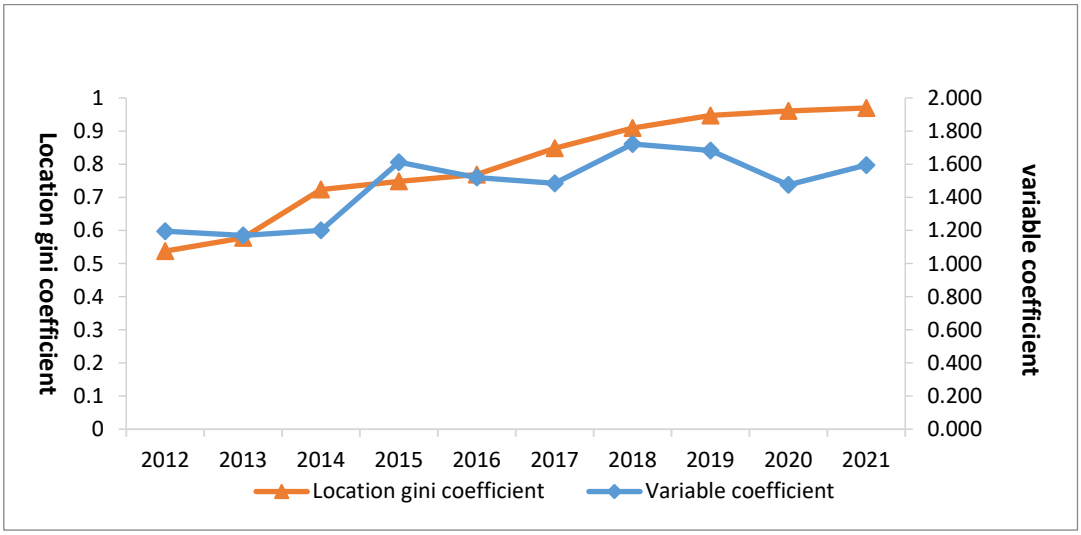

Figure 4: Changes in the relative difference of AI innovation output from 2012 to 2021

As shown in Figure 4, the relative difference of artificial intelligence technology innovation output of 31 provinces and cities in China has similar changes, and increases with the increase of time, showing an upward trend. As shown in Figure 4, the Gini coefficient of China's location is not less than 0.538, and the Gini coefficient is not less than 1.196. From the perspective of the development of artificial intelligence technology, the degree of unbalanced development of China's provinces and cities is relatively high. From the perspective of the fluctuation trend of the curve, it can be divided into three stages:

(1) The period from 2012 to 2015 was a rapid rising stage: the location Gini coefficient increased from 0.538 in 2012 to 0.748 in 2016, and the coefficient of variation increased from 1.196 in 2012 to 1.612 in 2015;

(2) From 2015 to 2018, it was a slow rising stage: the locational Gini coefficient increased from 0.748 in 2015 to 0.909 in 2018, and the coefficient of variation increased from 1.612 in 2015 to 1.722 in 2018;

(3) From 2018 to 2021, it was a slow development stage: The location Gini coefficient increased from 0.909 in 2018 to 0.970 in 2021, while the coefficient of variation decreased from 1.722 in 2018 to 1.595 in 2021. In the third stage, the distribution imbalance of artificial intelligence technology development

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increased, but the degree of variation decreased.

This is due to the fact that patent applications for AI technology in most regions of the study sample did not change much, while the number of patent applications in a few regions changed greatly, resulting in a decrease in the overall coefficient of variation. According to the data, the relative difference of China's artificial intelligence technology innovation output shows an upward trend on the whole, indicating that there is unbalanced development among provinces and cities in China, and the unbalanced development of artificial intelligence related technologies needs to be further improved.

5. Conclusion

5.1 Main discoveries

This paper selects the annual number of artificial intelligence technology industry-university-research cooperative invention patents in various provinces and cities in China (excluding Hong Kong, Macao and Taiwan) as samples, and analyzes the development level of China's artificial intelligence technology industry-university-research cooperative innovation output by using the literature analysis method, time series method and social network analysis method. The results show that:

(1) There is a certain degree of imbalance in the output of artificial intelligence technology innovation in China, and the eastern region has gradually increased compared with the central and western regions in the rapid development of artificial intelligence technology. In addition, the patent cooperation degree of more than one quarter of provinces is lower than the national average, reflecting the differences in the development and application of artificial intelligence technology in different regions

(2) Analyzing China's artificial intelligence technology industry-university-research cooperation innovation network, it is found that there is frequent cooperation among provinces and cities but low network density and uneven distribution of nodes, and eastern coastal provinces and cities perform better

In the cooperation network with industry-university-research institutions as nodes, the number of participating institutions increased and the scale of cooperation expanded, but the structural hole index of different institutions was significantly different, indicating that there were great differences in resource utilization capacity.

5.2 Improvement countermeasures from the perspective of innovation main body

First, strengthen the leading position of artificial intelligence enterprises in innovation, focus on market demand, and constantly improve the innovation ability of enterprises. The application scenario of artificial intelligence industry is constantly updated, and enterprise innovation must promote technological development by demand, and accelerate market application by technological development. The landing application of artificial intelligence has diversified characteristics. Enterprises should be sensitive to the diversified market demand and give timely feedback, actively participate in the research and development and innovation process, enhance innovation ability, improve innovation enthusiasm, and increase innovation output. At the same time, strengthen the leading position of artificial intelligence enterprises in innovation, and the application of artificial intelligence technology is changing with each new day. Enterprises should combine the actual situation of the market, make full use of internal and external innovation resources, control the market trend, and promote industrial progress.

Second, to promote the establishment of enterprise innovation team, enterprises in the construction of innovation team, must pay attention to the introduction and training of talents. For large enterprises, which usually have strong research and development capabilities and financial support, they can give full play to their advantages of large patent output and high conversion efficiency by cooperating with universities and research institutes, so as to promote the development of the entire industry. For small and medium-sized enterprises in the initial stage of development, they should pay more attention to cooperation with other enterprises, share technical resources, build a "cooperation network" model, and jointly train innovative talents.

Third, from the perspective of cooperative innovation network, although China's artificial intelligence technology cooperation and innovation regional network has established a wide range of cooperative relations, the density is relatively low and the node distribution is uneven. It indicates that the cooperative innovation network is loose, and there is a lack of resource flow channels and close communication and cooperation channels among various innovation subjects. However, the high centrality of the network

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shows that Beijing, Jiangsu, Guangdong and other regions have established extensive cooperation across the country, and have strong influence and control over other provinces and cities, which means that by playing the intermediary role of these core nodes, more innovation resources such as artificial intelligence technology, information, talent and market can be shared.

The last is to promote the differentiated and balanced development of innovation network. The spatial layout of China's artificial intelligence technology innovation output has unique characteristics, and the positive correlation with regional economic development level is not significant, and there is a law of geographical distance attenuation. It shows that the influence of core nodes on other nodes in the network decreases with the increase of geographical distance. In the long run, it may lead to polarization and exacerbate the development gap caused by differences in economic level and openness. Therefore, in the future development, it is necessary to pay attention to the spatial aggregation and differential characteristics of innovation output, strengthen knowledge exchange and resource sharing between regions, and promote the advantageous provinces to lead the development of the industry, and the inferior provinces to accelerate the application transformation. At the same time, regions with insufficient economic development momentum should seize the development opportunity of artificial intelligence to achieve leapfrog development. Provinces and cities should jointly promote the establishment of a platform for AI technology industry-university-research cooperation alliances, and make use of the characteristics of spatial differences to promote a balanced distribution of innovation resources among regions

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Appendix

Searches:(ALL=("Artificial Intelligence‖ or "artificial intelligence‖ OR "artificial intelligent‖ or "artificial intelligence‖ OR "artificial intellectual‖ or "artificial intellect‖ OR "artificial intelligence‖ or "artificial intelligent‖ or‖intelligence‖ OR"Speech Recognition‖ or ― computer vision/image recognition‖ or ―computer vision‖ or ―computer vision recognition‖ or "computer image recognition‖ OR ―deep learning‖ OR ―machine learning‖ OR ―machine learning platforms‖ OR ―natural language processing‖ OR ―smart robots‖ OR ―virtual assistants‖ OR ―gesture control‖ OR "personalized recommendation engines‖ or ―context aware computing‖ or ―video automatic content recognition" OR "speech to speech translation") AND (AD=[20120101 TO 20211231])AND (AP=((university OR college)AND (research institute OR research institute OR research center)) OR ((university OR college)AND (enterprise OR company)) OR ((enterprise OR company) AND (Research institute OR institute OR research center)))))