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ORIGINAL RESEARCH ARTICLE

Analysis of innovation chain structure of global geographic information industry

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ABSTRACT

Taking the geographic information industry as the research object, using the authorized invention patent data, this paper puts forward the research method of industrial innovation chain structure based on the geographic information industry chain. Then, from the perspective of overall structure and specific regional structure, the development status of the innovation chain is quantitatively evaluated, which is helpful to all countries in the world. The structural integrity and leading links of the innovation chain especially in China, the United States and Japan are compared and analyzed. The results show that: (1) from the perspective of the overall structure, the global innovation chain presents an "inverted triangle" structure due to the weak innovation ability of downstream links. From the perspective of specific regional structure, the innovation chain of geographic information industry in most countries and regions is incomplete, and there are broken links or isolated links. The global innovation chain except China has cracks between the upstream and downstream due to the relative weakness of the midstream links, showing "hourglass-shaped" structure with a wide upper part, narrow lower part and narrow middle part. (2) Relatively speaking, China's industrial innovation chain is relatively complete, and the midstream link has significant comparative advantages in the global market. However, the industry university research cooperation in the innovation chain is weak, the degree of marketization is low, and the technological competitiveness lags behind that of the United States.

Keywords: Innovation Chain; Patent Measurement; Innovation Leading Link; Comparative Advantage Analysis; Global Geographic Information Industry

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1. Introduction

In the era of knowledge economy, innovation has always been the focus of global attention. Marshall put forward the concept of innovation chain in 1992, and believed that the innovation process is a chain linked together and a process of interaction between different innovation subjects[1]. After foxon[2]. Barnfield[3] Jense[4] and Malerba[5] and other scholars' research, the concept, function and structure of innovation chain become clearer, the research on the interaction mechanism between different innovation chains becomes more in-depth, and the research idea extends from the meso level industry to the micro enterprise and macro national level[6,7]. Based on this, domestic scholars also understand the connotation pattern. basic structure, the layout and formation mechanism of innovation chain were studied[8-10], and the focus began to shift from the industrial chain, value chain, capital chain etc. to the effective allocation of different links and resources in the innovation chain[11-13]. Drawing on the above research results, the innovation chain refers to the innovation process as the link, which is a collection of various innovation activities that focuses on the division of labor, organic interaction, and connection and complementarity carried

out by the core technology branches of different upstream, mid-stream and downstream innovation links with production, learning and research as the innovation subject. The purpose of studying the innovation chain is to realize the achievement of science and technology, constantly optimize the structure of the innovation chain, and finally realize the improvement of the value creation of the whole industry. In the process of innovation, there are explicit or implicit flows of knowledge between different links of the innovation chain, and most of the innovation achievements are created by the subjects of multiple links using a variety of technologies.

With the rapid development of information technology and space technology, the geographic information industry, with the development and utilization of geographic information resources as the core, has become a strategic emerging industry that countries around the world focus on. Scholars mainly study the current situation of geographic information branch industries[14-16], national level industries through research and empirical analysis methods, trends[17,18] and the influencing factors of industrial development in a region or area[19-21]. Modern geographic information industry is different from traditional industries which is between manufacturing and service industries. It is an integrated industry across multiple technical fields, with significant technological innovation driven characteristics—the more technologies gathered in data, products and services, the greater the potential value and irreplaceability of the industry, the stronger the market share competitiveness. For the geographic information industry, the structure of the industrial innovation chain is complex, involving many innovation subjects, the technological development of each link is changing rapidly, the product renewal cycle is constantly shortened, and the strength comparison between different countries also changes subtly, which means that the frequency and requirements of the structural adjustment of the geographic information industrial innovation chain are higher than those of other industries. Therefore, after the innovation chain of geographic information industry starts to operate, we should design a scientific evaluation method to evaluate the current situation of the innovation chain structure in time, in order to provide references for the improvement of the overall output capacity of the innovation chain, and industrial innovation chain structure adjustment with the optimal resources combination and value maximization as the goal. Based on this, although the existing theories and methods of innovation capability evaluation are mainly obtained from the summary of the laws of high-tech manufacturing industry, and are still applicable to the geographic information industry to a certain extent, the research methods of innovation chain structure cannot be fully applicable to the geographic information industry. How to define and identify the innovation chain of geographic information industry? What is the structure of the innovation chain of the global geographic information industry? Where is the innovation chain of China's geographic information industry in the world? are practical problems that need to be studied urgently.

This study takes the geographic information industry as the research object, in view of the remarkable characteristics of the technology driven of the geographic information industry, takes technology as the core, and identifies the composition of different links of the industrial innovation chain on the basis of the industrial chain. Based on the above identification results, the global geographic information industry innovation chain from 2015 to 2019 is evaluated from the two levels of overall structure and specific regional structure by using the authorized invention patent data. Finally, it puts forward suggestions on the optimization of the development of China's geographic information industry innovation chain, which provides decision-making reference for China to cultivate a globally competitive geographic information industry.

2. Research methods

2.1 Research methods of industrial innovation chain structure

2.1.1 Subdivision of geographic information industry technology category

Internationally, the definition and classification

of geographic information industry began in North America and Western Europe. Since 1989, major enterprises, research institutions and organizations in the United States, Canada, Europe and Australia. have successively defined and classified the geographic information industry mainly based on geographic information system and satellite remote sensing industry[21]. The industrial statistical classification standard[22] issued by China divides the geographic information industry into six types: surveying and mapping services, remote sensing services, geographic information system services, satellite navigation and location services, geographic information hardware equipment and geographic information software equipment. Therefore, the geographic information industry defined by domestic and foreign scholars is mostly based on surveying and mapping, remote sensing, and geographic information systems, the scope of geographic information industry should include these contents, but there is still a lack of accurate patent retrieval expression for theoretical research and practical reference. In addition, due to the early start of foreign technology, China usually follows the pace of foreign research and pays attention to the retrieval of patents in the United States, Japan, and Western Europe, especially the retrieval of patents in countries or regions with mature technologies in the field of geographic information industry, therefore, cannot fully refer to the domestic classification system. The members of the research group of Zhejiang Geographic Information Industrial Park conducted in-depth research and analysis on the actual needs of enterprises in the industrial park by issuing questionnaires, decomposed the key technologies of the global geographic information industry, and provided the corresponding patent search expression[23]. Considering the operability of patent retrieval and research, this study refers to the classification system defined by the research group of Zhejiang Geographic Information Industrial Park, and divides the geographic information industry into four technical branches: engineering surveying and mapping, remote sensing detection, geographic information platform (including hardware and software) and geographic information system (**Table 1**).

2.1.2 Definition of innovation links with technology as the core

Geographic information industry chain is the foundation of constructing innovation chain. Referring to the existing research[24], the upstream, midstream and downstream of the geographic information industry chain are responsible for data collection, platform development and application service functions, respectively. The innovation chain is also divided into three links: upper, middle, and downstream. Each link is composed of technical branches used to realize the functions of each

Table 1. Technology branch of geographic information industry

Industrial technology branch	Content
Engineering surveying and mapping technology	Mainly refers to the level gauge, rangefinder, theodolite, total station and other measuring instruments, measurement data and method services, etc.
Remote sensing detection technology	It mainly refers to remote sensing platform, remote sensor technology and satellite receiving device. Remote sensing platform is a vehicle for placing various remote sensing instruments and providing them with technical support and working conditions. It can be divided into aerospace, aviation, ground remote sensing platform; remote sensor refers to the instrument or technology that can detect the electromagnetic wave radiated or reflected by ground objects and environment from a long distance, including photography and imaging, radar imaging, scanning imaging and non-image remote sensors; the receiving device mainly refers to the satellite receiver.
Geographic information platform (including hardware and software)	For the purpose of developing GIS integration platform or software and hardware equipment, the leading technology includes remote sensing image data processing and GIS data processing. Remote sensing image data processing is a primary processing technology for the information obtained by the remote sensor, mainly optical photography imaging and digital photogrammetry processing; GIS data processing is the technology of collecting, compressing storage, coding, enhancing, analyzing, integrating, grouping, organizing, calculating, retrieving, sorting, and outputting map data, remote sensing data, measured data, collection of multimedia data, etc.
Geographic Information System Technology	It is a geographical information system technology provides integrated and specialized application services for natural resources, disaster monitoring, daily life, urban operation and industrial development.

Table 2. Introduction to the innovation chain of geographic information industry

Link	Function	Brief introduction
Upper reaches	Data acquisition	It mainly includes remote sensing image data data acquisition of physical data (map data/measured data) and positioning and navigation information data, as well as basic theoretical research of related geographic information technology and hardware equipment. The production of this link is a two-way process from the combination of technology products to the results in the form of data, and then the results feed-back products and technology updates
Middle reaches	Platform development	By using the existing research results of geographic information technology, the collected data are processed, mainly for the purpose of improving the added value of data. The information integration of collected data is divided into remote sensing image processing and analysis and geographic information extraction and analysis. Combined with database management technology, the corresponding system integration platform or software and hardware equipment are formed and developed
Downstream	Application service	Applied to national defense and military affairs, government affairs, private enterprises and public information services. The first two fields involve many elements such as national security, and the corresponding technologies are generally not made public. In addition to the enterprises in the geographic information industry, the field of private enterprises also includes the integration of enterprise resources in the geographic information industry and other industries or the provision of direct technical services to other industries through the geographic information industry, forming scale effects and agglomeration effects, improving operation efficiency and accuracy, and driving the economic development of other industries. The field of public information services is mainly location-based services such as internet-oriented maps and vehicle navigation, which has the characteristics of public welfare and open sharing

link and the specific connotation of each link function is shown in **Table 2**.

2.1.3 Construction of innovation chain based on patent data

The patent data used are mainly from Derwent innovation index (DII). DII covers patent information of many countries, which is updated weekly and can be traced back to 1963, with relatively comprehensive data; and considering that the same patent may be filed in multiple countries and regions, resulting in multiple records of the same patent in the database, DII will include these related multiple applications as one record.

Data collection is mainly divided into three steps. (1) In order to make the results as representative of the current situation of the geographic information innovation chain as possible and reduce the impact of the lag in the growth of patent data due to the length of the patent application to authorization process, select the authorized invention patent data from 2015 to 2019, refer to the key technology patent search expression provided by the research group of Zhejiang Geographic Information Industry Park, construct a secondary technology branch search formula, and manually eliminate irrelevant patents. All data were retrieved on January 15, 2020, and information such as the number of patents, applicant's country, application time and patent classification number were counted. (2) Take the fourth level information of IPC (International Patent Classification) patents as the corresponding technology code, sort them according to the corresponding patent quantity, and extract the IPC classification number of the top 20 secondary technology branches as the basis for identifying the dominant technology of each technology branch and judging its innovation chain link[25], a total of 133 technology classification codes (**Table 3**). (3) Select IPC technology index table[25] as the division standard of technology field, and identify the links of each technology classification code according to the definition of innovation chain links, such as for example, G05D1 refers to the control of the position, channel, altitude or attitude of the vehicle on land, water, air or space, and it is classified into the upstream link according to the specific connotation of the innovation chain link (**Table 4**). (4) Use the results of the above steps, the industrial technology branches are classified into different innovation chain links with the technology field code as the intermediary.

Patent map is a comprehensive method of analyzing and utilizing patents. It combines quantitative and qualitative analysis to show patent information in the form of charts. These charts contain information closely related to the direction of tech-

Table 3. Decomposition results of geographic information industry patent technology

Primary technology branch	Secondary Technology Branch	IPC classification NO.	IPC classification number/pc	Number of patents/item
Remote sensing exploration and surveying industry	Remote sensing platform	G05D1, B64D47, B64C27, B64C39, G01C21, H04N7, B64D1, G06K9, H04N5, B64G1, G06T7, G01C11, B64C25, B64D45, B64C1, G01S7, G06F17, B64D27, G05B19, G01C25	110	1,701
	Remote sensor	G01S13, G01S7, G06K9, G01S17, G01C13, G01S19, G01S15, G01C5, G01C21, G06T7, G06F17, G01N21, G01J3, G01C25, G01C11, G06F19, G05D1, G01B21, G06N3, G01R29	58	769
	Satellite receiving device	G01S19, H01Q1, G01C11, H01Q21, H04N7, H02J7, H04N5, G01C21, G09B19, B60K35, G01S7, H02G7, H04L27, G06F16, G06F17	13	25
Engineering surveying and mapping industry	Measuring instrument	G01C1, G01C3, G01C5, G01C15, G01C25, G01S17, G01C11, G01B11, G02B23, G01C19, G05D3, G01S7, G01C9, G01C21, G01D11, H04N5, G01B21, G06T7, G01S11, G02B7	31	194
Geographic information platform industry (including hardware and software)	Remote sensing image data processing	G06K9, G06T7, G06T5, G06T3, G06N3, G06F17, G06T17, G06F16, G01N21, G06T1, G01S13, G01C11, G06T11, G06T9, G01S7, G06Q50, G06Q10, G01J3, G01S17, H04N7	58	1,571
	Geographic information data processing	G06K9, G06T7, G06F17, G06T5, G06T3, G06N3, G06F19, H04L29, G06Q50, G06T17, G06F16, G06Q10, G06T11, G06T1, G01C11, G01S13, G01N21, G06T9, G01S7, G09B29	78	2,014
Geographic Information System Industry	GIS application service	G06F16, G06F17, H04L29, G06Q50, G06Q10, G08G1, H04W4, H04N7, G05B19, G01C21, G06T17, H04L12, G01D21, H02J13, G01S19, G06K9, G05D1, H04W24, G08B21, G08B25, H04N21	45	390

Note: "number of patents/item" refers to the number of authorized invention patents corresponding to the top 20 Technology codes in each technology branch.

Table 4. Technical codes contained in the innovation chain

Link	IPC classification number
Upper reaches	G01B11, G01B21, G01C1, G01C3, G01C5, G01C9, G01C11, G01C13, G01C15, G01C19, G01C25, G01D11, G01D21, G01*R*29, G01S7, G01S11, G01S13, G01S15, G01S17, G01S19, G01N21, G01J3, G02B7, G02B23, G05D1, G05D3, G06F19, H01Q1, H01Q21, H04N5, H04L27, H04L29
Middle reaches	B60K35, G06K9, G06T7, G06N3, G06T1, G06T3, G06T5, G06T7, G06T9, G06T11, G06T17, G08B21, G08B25, G09B19, H02G7, H02J7, H02J13, H04L12, H04N5, H04N7, H04N21, H04L12, H04L29
Downstream	G06F16, G06F17, G06Q10, G06Q50, G08G1, H04W4, H04N7, G05B19, G01C21, G01D21, H02J13, G05D1, H04W24, G08B21, G08B25, H04N21, G09B29

nology research and development[26]. In order to identify which link in the innovation chain is dominant, the concept of patent map is introduced to chart the patent technology information in the innovation chain—the innovation chain is further defined as an innovation chain with four primary technology branches and their secondary technology branches as the core; considering that a technology branch is composed of multiple IPC, the concept of center of gravity is introduced, and each technology classification code of the innovation chain is given one-dimensional geometric coordinates to represent the links to which it belongs, so as to more intuitively express the structure of the innovation chain, that is, the IPCs that will be distributed in the upper, middle, and lower reaches of the innovation chain are assigned coordinate values of 1, 2, and 3, respectively. The number of patents corresponding to each IPC is used as the weight, and the "gravity" P of each secondary technology branch is calculated according to the gravity model[27], and the formula is as follows:

$$P = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i}, n \leqslant 133 \quad (1)$$

In the formula, X_i is the coordinate of the technical classification code i, W_i is the number of patents corresponding to it, and it is specified that the link to which the difference between the "center of

gravity" P of this branch and the coordinate value of which link is the smallest is classified. Similarly, calculate the "center of gravity" Q of four primary technology branches, and the formula is as follows:

$$Q = \frac{\sum_{a=1}^{m} P_a S_a}{\sum_{a=1}^{m} S_a} \tag{2}$$

Where, m is the number of secondary technology branches included in each primary technology branch, and S_a represents the number of patents corresponding to secondary branch a.

2.2 Evaluation method of industrial innovation chain structure

2.2.1 Overall structure and specific regional structure

The overall structure of the innovation chain of the geographic information industry refers to the structure of the innovation chain of the global geographic information industry from a macro perspective across geographical constraints. With reference to the principle of formula (1) (2), calculate the "center of gravity" *Gol* of the global geographic information industry on the innovation chain. The formula is as follows:

$$Gol = \frac{Up + 2Mid + 3Bot}{Up + Mid + Bot} \tag{3}$$

Where, *Up*, *Mid*, *Bot* stands for the the number of authorized invention patents included in the upstream, mid-stream and downstream link. Similarly, calculate the "center of gravity" *Rol* of the geographic information industry in a specific country or region in the innovation chain.

2.2.2 Comparative advantages of innovation chain

Quoting the revealed comparative advantage index (RCA index) and the trade competition index (NTB index)[28], this paper compares and analyzes the innovation comparative advantage of the innovation chain of geographic information industry in different countries. NTB index is a supplement to the indicative comparative advantage index, which is extended here as the technical competitiveness index (TTB index). The calculation formula of the two is as follows:

$$RCA_{ia} = \frac{X_{ia}/X_{it}}{X_{wa}/X_{wt}} \tag{4}$$

Where X_{ia} is the technology export of country i in link a, X_{wa} is the total technology export of link a in the world market, X_{it} is the total technology export of country i, and X_{wt} is the total technology export in the international market (here only refers to China, the United States and Japan). Generally speaking, RCA_{ia} closes to 1, means there is no relative advantage or disadvantage; when $RCA_{ia} > 1$, it means that the relative share of innovation link a in domestic technology exports is greater than the average share in the world. The industrial branch products or services contained in innovation link a collect more technological achievements, which are irreplaceable, and have comparative advantages in the international market. The larger the value, the greater the comparative advantage, and the stronger the innovation competitiveness; when $RCA_{ia} < 1$, it means that it has no comparative advantage in the international market, and the competitiveness of this link is relatively weak.

$$TTB_{it} = \frac{X_{it} - M_{it}}{X_{it} + M_{it}} \tag{5}$$

Where, X, M refers to the number of technology exports and imports, respectively. When $TTB_i > 0$ and farther away from 0, it means that the innovation output capacity of national i geographic information industry is greater; on the contrary, when $TTB_{it} < 0$ and farther away from 0, it means that the innovation chain of national i geographic information industry is more dependent on the innovation of other countries.

3. Analysis of innovation chain structure of Geographic Information Industry

3.1 Overall structure

According to formula (1) (2), the gravity center Q of remote sensing detection technology and engineering surveying and mapping technology

is biased to 1, which is subordinate to the upstream link; the gravity center *Q* of geographic information platform (including hardware and software) is biased to 2, which is subordinate to the midstream link; the technical center of gravity of GIS is biased towards 3, which is subordinate to downstream links (**Table 5**). Furthermore, according to the above division results of upstream–midstream–downstream technology branches of the innovation chain, it is calculated that the "center of gravity" *Gol* of the global scale geographic information industry in the innovation chain is 1.3, that is, the "center of gravity" is biased towards the upstream and midstream links. The main reason is that the number of globally authorized invention patents is mainly concentrated in the two major technology branches of remote sensing detection and geographic information platform, resulting in the "inverted triangle" structure of the global innovation chain due to the relative weakness of the innovation ability of the midstream and downstream links, That is, the upstream link is in the leading position, the innovation ability of the midstream link is relatively weak, and there are large cracks between the downstream link and the upstream and middle reaches.

Table 5. Distribution location of technology branches of geo-graphic information industry

Primary technology branch	Secondary technology branch	Secondary technology branch *P*	First level technology branch *Q*	Innovation chain link
Remote sensing detection industry	Remote sensing platform	1.16	1.12	Upper reaches
	Remote sensor	1.03		
Engineering surveying and mapping industry	Receiving device	1.06	1.03	
	Measuring instrument	1.03		
Geographic information platform industry (including hardware and software)	Remote sensing image data processing	1.96	2.06	Middle reaches
	Geographic information data processing	2.14		
Geographic Information System Industry	GIS application service	2.89	2.89	Downstream

Among them, the downstream is oriented to the application layer, closely integrated with the industry, with a wide technical boundary, and the cooperation between different types of innovation entities is the most. The number of Chinese patents in this technology field accounts for more than 80% of the world, and is still rising year by year. South Korea ranks second in the world, with a slower growth rate than China and the United States. There has been no significant growth between Japan and China in recent years.

The midstream is dominated by the geographic information platform industry, with technology research and development biased towards basic research and less direct application. The main types of research are institutions and colleges, and there is less cooperation with enterprises. After 2015, China firmly holds the position of the global technology research and development cutting-edge in this field, and the Chinese applicants in this field are mainly university research institutes.

The upstream link is dominated by basic data collection. There are many cooperation and contacts between different types of innovation subjects in the field of remote sensing detection, and technological innovation activities are highly concentrated in the United States, Japan, Germany, Britain, France and Russia and other European and American countries. The United States and Japan started early, with relatively large increases in patent applications, and the technology is in a mature stage. In the past five years, the innovation ability in the field of remote sensing detection technology in China, South Korea and other countries has developed by leaps and bounds. At present, the core technology in this field is mainly mastered by China, America and Japan. The pattern of technological innovation in the field of traditional engineering

measurement is highly concentrated in countries in the Eurasian continent such as China and Japan and Western European countries such as Germany, most of the innovation subjects come from Japan, and the main technology is mostly applied to engineering measurement instruments, and there is little cooperation between different types of innovation subjects. Compared with the midstream and downstream, the upstream technology research system is more detailed, mature and perfect, such technologies are mostly mastered by enterprises and colleges and universities. Among them, aviation technology involves national defense security and is usually not made public. At present, with the gradual development and improvement of civil remote sensing satellites, navigation satellites, such as Beidou navigation satellite positioning system, some ordinary civil patents have begun to appear. From the perspective of activity, the patent authorization of remote sensing detection, geographic information platform and geographic information system technology branches continues to increase, the number of subjects participating in innovation activities is also increasing, and the innovation activity is high. However, the engineering surveying and mapping technology branch has no significant growth trend in the past five years, reflecting the relative maturity of the upstream link which starts early and is in the mature stage; while the downstream link of market-oriented user terminals has not yet entered the mature stage, and is in the stage of rapid development. The number of related enterprises has increased, the market scale has increased, and has become a hot direction, with great development potential and market value.

3.2 Specific regional structure

3.2.1 Innovation chain integrity and leading link judgment

Patent priority refers to that after the patent applicant first filed a patent application in a certain country for his invention and creation, and then filed a patent application for the invention and creation of the same subject within the legal period, his subsequent application can take the date of the first patent application as his application date, and the patent applicant enjoys priority according to law, resulting in a group of applications in different countries or international patent organizations with common priority. The patent documents with the same or basically the same content published or approved for many times produce a patent family[23], and the patents of the same patent family are the continuous improvement of the technology on the basis of the original patented technology. In order to explore the originality of technology, this study counted the number of patent authorizations in different countries according to the country of the applicant who authorized the invention patent and the country with the earliest priority. Due to space constraints, countries with too few or missing statistical data samples (such as Canada, which applied for 6 authorized invention patents from 2015 to 2019, with 0 priority) were omitted. From the perspective of patent applicants' countries, some national innovation chains are not complete, and there are chain breaks. Short chains or orphan rings (**Table 6**). China and the United States are in the leading position in the global innovation chain, of which China is prone to upstream and midstream link, while the United States extends to the downstream link; Japan's reference value tends to be downstream, but it lacks the innovation ability of the midstream link; compared with the downstream links with up to 265 authorized invention patents, the innovation ability of midstream links in South Korea is weak. The two western European countries, Germany and France, lead the upstream link than the downstream link; Sweden, Finland, and India tend to be in the midstream link, while Norway and Australia are in the middle and lower reaches. Israel's development is relatively balanced, but, due to the lack of data in the statistical results of these countries in recent five years, the results are only for experimental reference.

From the perspective of patent priority, on the one hand, there is a serious lack of links in the global innovation chain. Except that the midstream links in China's innovation chain are relatively complete, other countries have varying degrees of midstream links missing, resulting in the global innovation chain except China being wide at the top

due to the relative weakness of the midstream links. The lower part is narrow, and the middle part is thin and narrow, "hourglass-shaped" structure, and there are large cracks in the upstream and downstream links; on the other hand, according to the invention patents that have appeared in the past five years, most of the core technologies of the upstream link are mastered in the United States and some are mastered by China, Japan, South Korea, Australia and Germany; the core technology of the midstream link is less than that of other links, and most of it is mastered by China..

In general, the number of authorized invention patents according to the country of patent applicant is much higher than that according to the country of priority, especially in the midstream of the innovation chain. There may be two reasons: first, patent priority is the first basis for judging the country of origin of the patented technology. For patent applications without priority, the earliest applicant country of the patent shall prevail. The small number of authorized patents obtained according to the statistics of priority countries means that most countries have weak awareness of intellectual property rights in the field of geographic information industry and weak awareness of protecting their own technological innovation achievements and market interests. There are deficiencies in intellectual property management and avoiding intellectual property operation risks; second, due to the rapid development of the global geographic information industry, patent innovation entities in many countries prefer to distribute patents in their own or nearby markets. The number and field distribution of patent distribution in other parts of the world are weak, providing a good window of opportunity for developing countries such as China, It also makes the technological innovation of the late developing countries have a certain path dependence on the existing original technologies of the first countries that hold most of the patent priorities, and laterally reflects the current situation that the late developing countries, as new industrial entrants, have less truly valuable geographic information technology.

Table 6. Current situation of innovation chains of major national geographic information industries

Different countries	Upper reaches		Middle reaches		Downstream		Application country *RoI*	Priority country *RoI*
	Application quantity /item	Priority /item	Application /item	Priority /item	Application /item	Priority /item		
China	3 191	57	1 513	13	365	13	1.4	1.5
USA	38	44	3	3	105	68	2.5	2.2
Japan	16	16	0	0	21	10	2.1	1.8
Germany	6	5	1	1	3	1	1.7	1.4
France	6	6	0	0	1	0	1.3	1.0
The Republic of Korea	7	7	0	0	265	7	2.9	2.0
Israel	1	1	1	0	1	1	2.0	2.0
Sweden	1	1	2	0	0	0	1.7	1.0
Australia	1	0	3	0	5	4	2.4	3.0
Finland	1	1	6	0	0	0	1.9	1.0
India	1	1	7	0	0	0	1.9	1.0
Norway	1	1	8	0	5	0	2.3	1.0

3.2.2 Comparison of innovation chain structure of Geographic Information Industry between among the United States, Japan and China

In the innovation chain of global geographic information industry, the total number of invention patents authorized by the China, Japan and the United States are 11,758 (upstream), 1,224 (midstream) and 4,106 (downstream). Through statistical analysis of the top 100 institutions in the industrial innovation chain of the three countries and their patent information (**Table 7**), it is found that more than 50% of China's R & D subjects are research institutions and colleges and universities, with more government investment and support, and less cooperation between industry, university and research, especially in the upstream link. On the one hand, the upstream link belongs to a professional market with certain technical difficulties and depth; on the other hand, geographic information is an important

Table 7. Features comparison of geographic information industry innovation chains in China, US and Japan based on patent data

Features	Country		
	China	**USA**	**Japan**
Subject (applicant type)	Research institutions and colleges and universities have less industry–university–research cooperation	Enterprise oriented	Enterprise oriented
Mode	Technology transfer. Independent research. Cooperative research. Public service (for military and government)	Technology transfer. Independent research. Cooperative research. Technical services. Public service platform (for military. Government. Enterprise. Public). Business service platform. Market mechanism	Technology transfer. Independent research. Cooperative research. Public service platform (for military. Government. Enterprise. Public). Business service platform
Investment	Government oriented	Enterprise. Government. Marketization	Enterprise. Government
Intellectual property (patent layout)	The domestic layout is mainly in the domestic protection stage	Large layout coverage, overseas expansion stage of the whole innovation chain	Large layout coverage, upstream. Downstream is in overseas expansion stage

resource related to national security, and mature technology is basically still in the domestic protection stage, limiting the technology input of core technology to private enterprises. Most of the innovation entities in the United States and Japan are enterprise types. Among them, the United States has a high degree of marketization of its innovation chain and has more business service platforms, while China is mostly public welfare service platforms, and the services are mainly oriented to government management and national defense and military fields; there are also public service platforms and commercial service platforms in Japan, but due to the small scale of Japanese geographic information enterprises, most of which are enterprises in the upstream engineering measurement technology branch and the downstream electronic navigation service field, other fields have not yet formed a market-oriented mechanism. The innovation subjects of GIS data processing branches and downstream links are mostly enterprises in the three countries and even globally, involving a wide range of technical fields, and it is difficult to have monopoly enterprises. Besides, the geographic information industry of Japan and the United States has launched a more comprehensive patent layout, formed a high-strength patent barrier, and implemented strategic organization and management of independent intellectual property rights. While the patents related to China's geographic information industry are mainly distributed in China, with a low degree of expansion overseas, and there is a risk of infringement.

From the comparative advantage index (**Table 8**), China has significant comparative advantages in the upstream, midstream and downstream links compared with USA and Japan, the United States has comparative advantages in the downstream link, and Japan is in the upstream link; however, from the perspective of technology competition index, compared with the United States, China's technological competitiveness needs to be further improved. China's patent technology citations mainly come from self-citations and citations to the United States. The ratio between the number of technology citations from China to the United States and the number of patent citations from the United States to China is 5:1, that is, technological innovation in China's geographic information industry is highly dependent on the United States. Specifically, as the only developing country among the three countries, China has rapid technological development, but its technological "quality effect" is relatively weak. Enterprises in developed countries have a complete industrial chain ecosystem, which is deeply integrated with the new generation of information technology vertically and widely used in all walks of life horizontally, with a high degree of popularity, which also means that they have strong industry cohesion and attraction; although China's geographic information industry also has comparative advantages in the downstream, the advantages of

the innovation chain are still mainly in the midstream and upstream, the top data and core technology are mainly in the hands of the government and giant enterprises. Opening up the upstream and downstream of the industry and promoting the "virtual to real" of geographic information can make the value of geographic information resources be of greater significance. However, the current application of government and military is still the main market of China's geographic information industry, government application. Popularization and marketization have become the important development and transformation direction of the industry.

Table 8. Comparison results of comparative advantages of innovation chains among China, US and Japan

Parameter	Country		
	USA	China	Japan
Upstream comparative advantage	1.0	2.9	3.2
Midstream comparative advantage	0.9	4.1	1.3
Downstream comparative advantage	1.2	2.3	0.0
Technical competitiveness index	0.45	-0.05	-0.76

4. Conclusion and discussion

(1) From the perspective of the overall structure of the innovation chain, the global geographic information industry is relatively complete, and different links of the chain have their unique supporting technologies to realize the functions of their links; from the specific regional structure of the innovation chain, it is found that except China and the United States, the innovation chain of geographic information industry in most countries and regions is not complete and there are broken links, isolated ring, and the gap between the upstream and downstream due to the relative weakness of the innovation capacity in the midstream link. The global innovation chain except China has a gap between the upstream and downstream due to the relative weakness of the midstream link, which is wide in the upper part, narrow in the lower part and narrow and thin in the middle part, forming "hourglass-shaped" structure.

(2) The basic functions of China's geographic information industry innovation chain had been relatively mature, and it is in a leading position in the world, and the midstream link has significant comparative advantages. However, the industry–university–research cooperation in the industrial innovation chain is weak, and there are few joint research and development or entrusted research and development. University scientific research institutions and the government are far less sensitive to the market than enterprises. If their research results cannot be smoothly transferred to enterprises, and the independent innovation ability of enterprises is weaker than that of universities and scientific research institutions, the cost of technology introduction, especially the purchase cost of core technology, is too high. In the long run, the innovation results will be difficult to market and industrialization, and the domestic service objects are mostly national institutions, and the service intensity and depth to enterprises and the public are not enough, which further hinders the improvement of innovation ability and the optimization of innovation system.

(3) China should regularly organize global, national and regional industry-university-research cooperation forums led by the government or building platforms to promote the effective combination of various production factors required for technological innovation. In addition, we should take advantage of the formed technological competitive advantages in the midstream link and pay attention to the technological innovation in the direction of geographic information platforms (including hardware and software). The layout of patents and the construction of patent barriers focus on the development of the middle and upper reaches of the geographic information industry around the field of advantageous technology, and the main body of innovation is in the middle. For GIS data processing branches and downstream links where the main innovation bodies are enterprises in China, the United States, Japan, and even globally, it is necessary to promote the connection and cooperation between enterprises and high-level talent teams such as universities and research institutions in and outside the region to effectively extend innovation chain, build the national geographic information

industry's full innovation chain advantage, and finally walk out an industrial development road from "point" (advanced technology field) to "face" (innovation cluster).

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Conflict of interest

The authors declare that they have no conflict of interest.

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