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Review

Knowledge Map Analysis of Industry–University Research Cooperation Policy Research Based on CNKI and WOS Visualization in China

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Abstract: The field of industry–university research cooperation policy is about to enter a new stage. It is necessary to systematically sort and summarize the literature, both at home and abroad, that has been produced in recent years. Through knowledge map analysis of the current situation regarding the development of industry–university research cooperation policy, from both domestic and foreign perspectives, taking the core documents included in the Web of Science and China National Knowledge Infrastructure database as samples, and through visual research on the time context, author, organization, theme, and other key nodes of industry–university research cooperation policy research, with the help of CiteSpace and NoteExpress measurement software, we can draw the following conclusions. Domestic research is relatively focused on colleges and universities; that is, industry–university research cooperation as a mechanism to cultivate innovative talents and improve scientific research and enhance social services, while foreign countries pay more attention to the technological utilization and technological innovation of enterprises and their accompanying economic benefits. Domestic and foreign research have their own characteristics, and the research quality of the two is equal. Generally speaking, research on the policy of domestic university research cooperation should focus on the following three points in the future: It must be closely related to the functions of colleges and universities, the nature of enterprises, and social needs; we must attach great importance to empirical research; and we must pay attention to cross-organizational research.

Keywords: knowledge graph; industry–university research cooperation; CiteSpace; NoteExpress; visualization

Citation: Li, J.; Sun, X.; Dai, X.; Zhang, J.; Liu, B. Knowledge Map Analysis of Industry–University Research Cooperation Policy Research Based on CNKI and WOS Visualization in China. *Sustainability* **2022**, *14*, 7862. https://doi.org/10.3390/su14137862

Academic Editors: Michele Grimaldi and Víctor Jesús García-Morales

Received: 29 April 2022
Accepted: 16 June 2022
Published: 28 June 2022

1. Introduction

Science and technology are the primary productive forces, and based on the needs of scientific research and economic and social development, research topics such as industry–university research cooperation have emerged, aiming to further promote the efficient transformation of scientific and technological achievements into economic achievements. According to the latest data released by the organization for Economic Cooperation (OECD) on the proportion of total R&D expenditure in GDP (Figure 1), countries all over the world have paid attention to scientific research and experimental development in terms of scientific research investment. The field of science and technology is a double-edged sword, which has a great impact on the politics, economy, and culture of all countries in the world. In order to reduce the negative impact and promote the steady progress of scientific research achievements in the direction of human development, industry–university research cooperation has become a focus of attention of governments, society, and professional scholars, as well as other subjects. With the deepening of research, policy concerning industry–university research cooperation has also emerged, which has become

a research theme at home and abroad, and is an important measure to solve the "double-edged sword" of science and technology.

Figure 1. Research and experimental development (R&D) investment from 2017–2020.

Driven by the third scientific and technological revolution, industry–university research cooperation has gradually become a strong driving force behind economic and social development. The most classic case of industry–university research cooperation is the "Silicon Valley" economic miracle, created with the help of Stanford University. According to Baidu Encyclopedia's definition, industry–university research cooperation refers to the cooperation between enterprises, scientific research institutes, and colleges and universities. It usually refers to the cooperation between enterprises as the technology demander and scientific research institutes or colleges and universities as the technology supplier. Its essence is the effective combination of the various production factors required to promote technological innovation. It includes intra-university industry–university research cooperation mode, two-way consortium cooperation mode, multi-directional consortium cooperation mode, intermediary coordination cooperation mode, and other cooperation modes. The research on the policy of industry–university research cooperation is a multi-disciplinary field, including enterprises, universities, and research institutes.

At present, in the domains of both natural science and social science, facing the increasingly complex background of the times, the significance of scientific research is becoming more and more prominent. After a period of exploration and progress, industry–university research cooperation has entered the stage of rational development. At the same time, the policy of industry–university research cooperation is also facing new opportunities and challenges. The academic research on the policy of industry–university research cooperation does not show a clear systematic context. At the same time, the combing and summation of foreign literature by domestic scholars has failed to produce effective results, almost resulting in the phenomenon of "looking for sentences behind closed doors", and has failed to effectively absorb and draw lessons from foreign research results. Based on this, this paper selects data from the literature at home and abroad from 2017 to 2021, using WOS (Web of Science) and CNKI (China National Knowledge Infrastructure) as the databases. It carries out visual analysis with the help of literature measurement software and answers the following questions on the basis of combing the data for publication trend,

author, institutional cooperation network, issuing country, discipline direction, research theme, and other information relating to industry–university research cooperation policy research at home and abroad.

First, what is the current research trend at home and abroad? What are the characteristics? Second, what are the research hotspots in terms of the policy of industry–university research cooperation at home and abroad? Third, what is the latest research trend and development direction of industry–university research cooperation policy? With the extension of the functions of colleges and universities from talent cultivation and scientific research to social services, by comparing the development process of industry–university research cooperation policy, we can find that great changes have taken place. Moreover, under the increasingly complex background of the times, studies on industry–university research cooperation policy represent a novel research direction.

2. Data Sources and Research Tools

The first step of the knowledge map analysis method includes the sourcing of the data and the selection of methods. The data sources studied in this paper are CNKI and WOS, which represent the most authoritative databases at home and abroad, respectively.

2.1. Data Collection

In order to fully assess the reliability and integrity of data, the domestic literature was screened through the CNKI platform. The data sources were Peking University core, EI, and CSSCI. The retrieval conditions were: the theme of industry–university research policy; the title of industry–university research combination or industry–university research cooperation; the matching method, determined to be accurate; and the time span of 2011–2021. In order to prevent the contents of masters' theses and conferences from overlapping with the contents of periodicals, masters' theses and conference theses, as well as some other forms found in the literature, such as book reviews, conferences, the solicitation of contributions, and news irrelevant to the research topic, were eliminated. Due to the requirements of research tools, CNKI documents needed to export the title information in the form of refworks text, which was then cleaned by using the NoteExpress software (NoteExpress v3.6.0.9220, http://www.inoteexpress.com, accessed on 10 June 2022). At the same time, before exporting refworks text information, one person screened and another person checked the documents, with a final total of 927 documents obtained. The foreign literature was screened through WOS, and the following search conditions were entered in the basic search: the subject word is industry–university research policy, and the synonyms are combinations of industry, university and research, industry–university research cooperation and Industry University Research Association. The document type is article and review; the language is English; the time span is from 2017–2021; and the database is the core collection of Web of Science. A total of 893 documents were retrieved.

2.2. Research Tool

The research tools used were the NoteExpress and CiteSpace software (CiteSpace © 2003–2021 Chaomei Chen, http://cluster.cis.drexel.edu/~cchen/citespace/, accessed on 10 June 2022), types of literature measurement software. NoteExpress is a professional literature retrieval and management system developed by the Beijing Aegean software company. Its core function covers all aspects of knowledge management, including "knowledge collection, management, application and mining". CiteSpace is a visual software developed based on Java for analysis and measurement, which can transform the text title data of CNKI and WOS, and realize the operation of the CO citation of documents. Due to the limitation of the software itself, this paper mainly uses CiteSpace software to analyze the keyword co-occurrence clustering and keyword frontier trend of CNKI documents, so as to realize an overall understanding of the research topic.

3. Research Status of Industry–University Research Cooperation Policy in China

The idea of industry–university research cooperation has been put forward in the early stage of China's science and technology system reform. The main purpose is to solve the problem of the "two skins" of science and technology and economy. Many countries in the world regard the strengthening of industry–university research cooperation as important work. At the same time, both at home and abroad, researchers have paid extensive attention to the policy of industry–university research cooperation. In this paper, we first conduct knowledge map analysis of the domestic research situation, so as to obtain some of the directions and themes of the research on the policy of university research cooperation in China.

3.1. Issuance of Policies on Industry–University Research Cooperation

According to the above search conditions, a total of 927 documents were obtained through the analysis of NoteExpress software. Figure 2 shows the change trend of industry–university research cooperation policy research documents from 2011 to 2021. As can be seen from Figure 2, the literature on the policy research of production university research cooperation generally shows a linear downward trend. The literature decline in the past decade can be divided into two stages according to the speed of decline. First, from 2011 to 2018, the number of core papers decreased sharply in a stage of rapid decline. At this moment in time, according to China's innovation system of combining industry, university, and research, it had been more than ten years, and the research on industry–university research cooperation gradually fell into a trough. Second, from 2019 to 2021, the number of core papers published in this stage stopped declining and remained relatively stable. The annual number of papers published fluctuated around 35. Combined with China's successful entry into the ranks of innovative countries in 2020, it shows that domestic industry–university research cooperation is in a saturated state. However, considering the important value of future scientific and technological innovation, the research on industry–university research cooperation policies will gradually recover in the future.

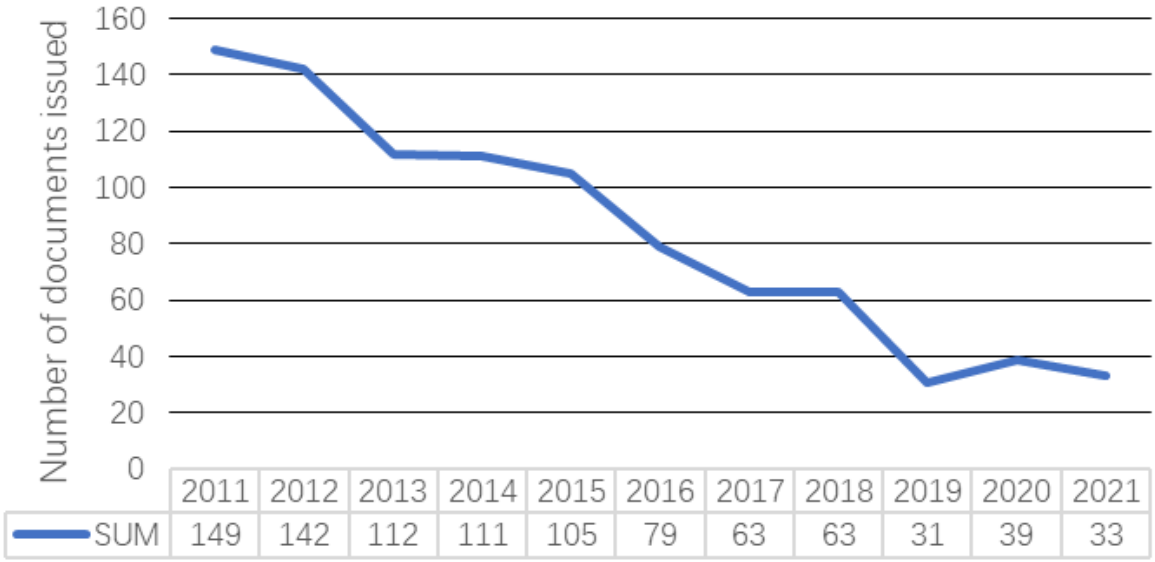


Figure 2. General trend of the literature on the policy research of industry–university research cooperation.

This paper selected the top ten journals with the highest number of papers on related topics from 2011 to 2021 (see Figure 3). According to the distribution of source journals in the literature every year, it can be seen that the largest number of papers can be found in "science and technology in colleges and universities in China", with a number of 149; the second is "research on science and technology management", with a number of 93. Among

them, 90% of the journals belong to the social sciences, which shows that the humanities and social sciences in domestic academic circles pay more attention to the policy research of industry–university research cooperation.

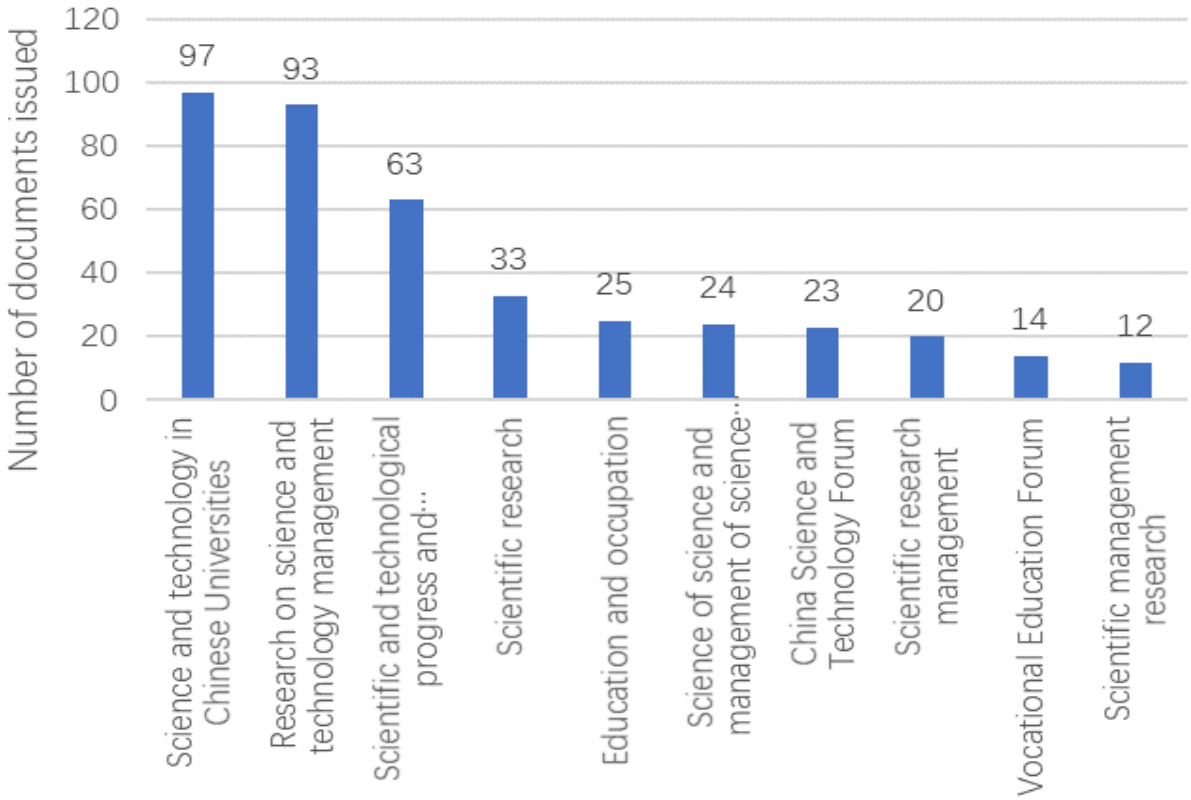


Figure 3. Source distribution of articles on the policy research of industry–university research cooperation.

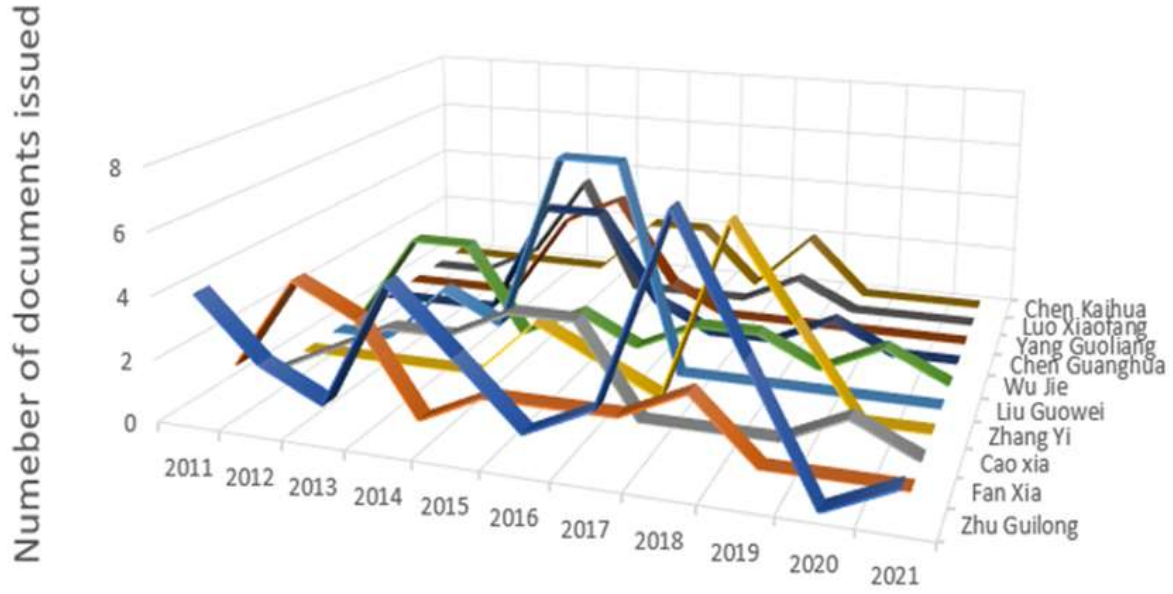
3.2. Authors of Policy Research on Industry–University Research Cooperation

Through the analysis of 927 documents from the literature by NoteExpress, it is concluded that the total number of authors studying the industry–university research cooperation policy and publishing via Peking University, EI, or CSSCI from 2011 to 2021 is 1606, and the average number of authors of each article is 1.73. Table 1 clearly shows a list of authors with a high number of papers in the field of industry–university research cooperation policy research (six papers and above). The author with the largest number of papers is Zhu Guilong, with a number of 31, followed by Fan Xia, with 13 articles.

Table 1. Statistics on the number of documents issued by authors of policy research on industry–university research cooperation.

Serial Number	Author	Number of Documents Issued (Articles)	Serial Number	Author	Number of Documents Issued (Articles)
1	Zhu Guilong	31	8	Yang Guoliang	8
2	Fan Xia	13	9	Luo Xiaofang	6
3	Cao Xia	12	10	Chen Kaihua	6
4	Zhang Yi	12	11	Li Baizhou	6
5	Liu Guowei	11	12	Gao Xia	6
6	Wu Jie	10	13	Long Minglian	6
7	Chen Guanghua	10			

From the relevant data collected and extracted from the top 10 authors, Figure 4 clearly shows the publishing frequency of each author from 2011 to 2021. It is found that Zhu Guilong is the most active in terms of publishing volume, with an output almost every year, followed by Fan Xia, Cao Xia, and Zhang Yi. Zhu Guilong has the longest research time and Yang Guoliang has the shortest research time.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Zhu Guilong	4	2	1	5	3	1	2	8	4	0	1
Fan Xia	1	4	3	0	1	1	1	2	0	0	0
Cao xia	0	1	2	2	3	3	0	0	0	1	0
Zhang Yi	0	0	0	0	2	1	0	6	3	0	0
Liu Guowei	0	0	2	1	7	7	0	0	0	0	0
Wu Jie	0	3	3	0	1	0	1	1	0	1	0
Chen Guanghua	0	0	0	4	4	1	0	0	1	0	0
Yang Guoliang	0	0	0	3	4	1	0	0	0	0	0
Luo Xiaofang	0	0	1	4	0	0	0	1	0	0	0
Chen Kaihua	0	0	0	0	2	2	0	2	0	0	0

Figure 4. Publishing trends of authors of industry–university research cooperation policy research.

In order to further understand author cooperation, we ran the CiteSpace software and set the node type as the author to obtain the author's collinear network knowledge map with the number of nodes, n = 358, the number of connections, e = 159, and a density of 0.0025 (see Figures 4 and 5). As can be seen from the figure, the scholar with the largest number of nodes is Zhu Guilong, followed by Fan Xia, Zhang Yi, Chen Kaihua, Liu Guowei, Cao Xia, and Chen Guanghua. Due to the mutual exchange and cooperation of various scholars, several sub-author network structures are formed in the atlas, notably a network structure led by Zhu Guilong, Fan Xia, and Liu Guowei. The figure shows that several high-yield authors have low cooperation, which is mainly reflected in the academic exchanges and contact between Zhu Guilong, Zhang Yi, and Chen Kaihua, and less cooperation is seen with other scholars with large amount of papers (such as Liu Guowei, Chen Guanghua, etc.). There are many scholars in separate nodes, such as Wu Jie, Huang Jinsong, and Yuan Yijun. On the surface, it appears that Chinese scholars do not have a strong sense of communication and cooperation in the research of industry–university research cooperation policy, and the academic exchange and cooperation of scholars needs to be strengthened.

Figure 5. The distribution of the author cooperation network in the policy research of industry–university research cooperation.

3.3. Information on Policy Research Institutions of Industry–University Research Cooperation

The document information imported by CiteSpace was extracted. From 2011 to 2021, a total of 304 document-issuing institutions (including individual institutions and joint institutions) participated in this topic and were cited, representing high-quality achievements in this field. Table 2 shows the ranking of the top ten institutions cited. The School of Business Administration of South China University of Technology has the most citations, with 22 citations from 2011–2021, followed by the School of Economics and Management of Harbin Engineering University, with 15 citations from 2011–2021. Institutions represented by universities of science and technology have become the main driving force behind the study of the policy of industry–university research cooperation. Among the institutions studying the policy of industry–university research cooperation, Guangdong is the most representative, indicating that economically developed and open experimental areas have certain regional advantages in the research of industry–university research cooperation policy, especially in the south. Among these institutions, business administration, economic management, and other colleges are the main colleges studying the policy of industry–university research cooperation.

In order to further analyze the cooperation of institutions, the node type is set as institutions, and a co-occurrence knowledge map of institutions with 305 nodes, 0 connections, and 0 density is obtained (see Figure 6). From the generated map, it can be found that the school of Business Administration of South China University of Technology and the School of Economics and Management of Harbin Engineering University have larger nodes; the larger the nodes are, the more numerous they are. This shows that the researchers of the two institutions have published more documents and have a strong academic research ability in China. From the large number of nodes, and with the number of connections in the figure being 0, it can be seen that the connection between various institutions is quite loose,

representing almost no connection, and reflecting the lack of cooperation consciousness between each other.

Table 2. Cited statistics of industry–university research cooperation policy research institutions.

Serial Number	Institution	Type of Institution	Region	Cited Quantity (Times)
1	School of Business Administration, South China University of Technology	Science and Engineering	Guangdong Province	22
2	School of Economics and Management, Harbin Engineering University	Science and Engineering	Heilongjiang Province	15
3	School of Management, Guangdong Ocean University School of Business Administration, South China University of Technology	Agriculture and Forestry Science and Engineering	Guangdong Province	5
4	School of Economics and Management, Inner Mongolia University	Comprehensive Class	Inner Mongolia Autonomous Region	5
5	Zhongkai College of Agricultural Engineering	Agriculture and Forestry	Guangdong Province	4
6	Guilin Institute of Aerospace Technology	Science and Engineering	Guangxi Province	4
7	Business School of Central South University	Comprehensive Class	Hunan Province	4
8	College of Grammar and Law, Northeastern University	Science and Engineering	Liaoning Province	4
9	School of Management, Xi'an Jiaotong University	Comprehensive Class	Shaanxi Province	3
10	School of Management, Jilin University	Comprehensive Class	Jilin Province	3

Figure 6. Institutional co-occurrence knowledge map of industry–university research cooperation policy research.

3.4. Key Issues of the Policy Research of Industry–University Research Cooperation

Research hotspots reflect the research focus and direction of a research field, which is of great significance for an in-depth understanding and analysis of the research content in this field. Keywords are the core of a document. The high frequency of keywords

in a certain field reflects the research hotspot in this field. Keyword cluster analysis is based on keyword co-occurrence analysis, which simplifies the keyword co-occurrence network relationship into a relatively small number of clusters through the method of cluster statistics. This paper analyzes the research hotspots of industry–university research cooperation policy by keyword cluster analysis, and explores the research hotspots of industry–university research cooperation policy.

Using CiteSpace software to extract the keywords of literature data, we set the node type as the keyword, and set the three groups of C, CC, and CCV to have a threshold of 1, 1, and 20; 1, 1, and 20; and 3, 3, and 20, respectively. Other parameter values are set by default. Based on the keyword knowledge network map, the LLR algorithm is selected to obtain the keyword clustering network map as shown in Figure 7, in which the number of nodes is 963, the number of connections is 1419, and the network density is 0.0031. The figure shows 18 clusters of the phrases "industry university research", "university", "mode", "collaborative innovation", "cooperative education", "higher vocational colleges", "technological innovation", "innovation network", "cooperation mode", "innovation", "countermeasures", "benefit distribution", "knowledge transfer", "cooperative innovation", "performance evaluation", "performance evaluation", "innovation performance", "scientific and technological innovation", and "supporting policies". This reflects the research hotspots in the field of the policy of domestic university research cooperation.

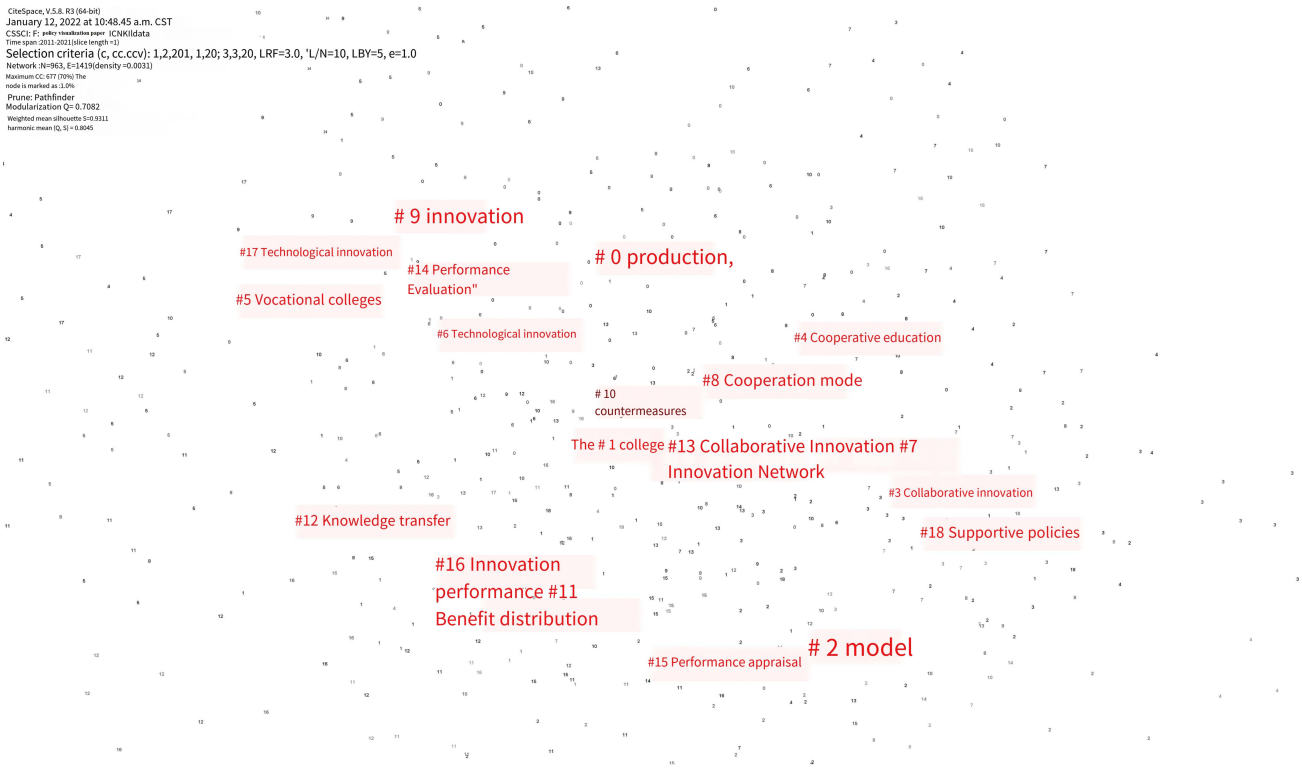


Figure 7. Keyword clustering network map of industry–university research cooperation policy research.

Based on the knowledge map of keyword clustering, the log likelihood rate (one of the clustering tag word extraction algorithms) is obtained in "cluster explorer", and the keyword co-occurrence network clustering table is obtained (see Table 3).

Table 3. Industry–university research cooperation policy research keyword co-occurrence network clustering table.

Cluster Number	Cluster Size	Tag Words (Select the First Five)
0	75	Innovative mode; Reform of scientific research system; Enterprise postdoctoral; Practical education; Multi-party cooperation
1	59	Industry–university research cooperation; Scientific research institutions; Production enterprises; educational services; Wenzhou enterprises
2	56	Industry–university research cooperation; Industrial design; Subject practice; Studio system; General local universities
3	46	Collaborative innovation; Joint construction of ministry and University; Government industry–university research cooperation; News communication; Personnel training
4	42	Industry–university research cooperation; Cultivation process; Cultivation effect; Innovation environment; Knowledge innovation
5	38	Industry–university research cooperation; Local universities; School running mode; Transformation and development; Educational model
6	38	Industry–university research cooperation; Technological innovation Enterprise LED; Vocational colleges; Western Hunan
7	37	Innovation network; Industry–university research cooperation; Spatiotemporal evolution; Network evolution; Patent measurement
8	37	Industry–university research cooperation; Cooperation mode; Cooperation mechanism; Research review; Low-carbon industry–university research cooperation
9	33	Industry–university research cooperation; Absorptive capacity; Adjusting variables; Educational attribute; Knowledge transfer
10	33	Industry–university research cooperation; Absorptive capacity; Adjusting variables; Educational attribute; Knowledge transfer
11	32	Industry–university research cooperation; Game analysis; Mode selection; Industry–university research cooperation and innovation; Technical value
12	28	Industry–university research cooperation; Knowledge transfer; Case studies; Innovation ability; Model evolution
13	27	Cooperative innovation; Industry–university research cooperation; Knowledge management; Innovation management; External knowledge network
14	27	Industry–university research cooperation; Performance evaluation; Theoretical model; Index system; Evaluation method
15	26	Industry–university research cooperation; Bibliometrics; Knowledge base; International research; Research hotspots
16	25	Industry–university research cooperation; Team size; R&D team; Team structure; Team quality
17	11	Industry–university research cooperation; R&D platform; Jiangsu Aoshen; High-performance fiber materials; Innovation network
18	7	Supporting policies; High-tech industry; Quantitative comparison; Policy text; Industrial competitiveness

By analyzing the keywords in each cluster, it is found that the research contents of each cluster intersect with each other. Therefore, it can be seen that the domestic research on the policy of industry–university research cooperation can be summarized into three thematic areas: "industry–university research cooperation", "innovation", and "universities". Three important related clusters of "industry university research", "universities", and "innovation" are taken as an example (Figure 8). In the literature, the industry university research cluster first appeared in Tian Huajie's [1] *Effect and Problem Thinking of Industry–University Research Cooperation Mode* in 2011. Since 2011, the number of results in this cluster has increased, and the number of studies containing the keyword "industry university research" has increased rapidly. Moreover, over time, the attention paid to this cluster has been maintained at a high level. The keyword emergence diagram (Figure 9) also shows that the keyword "industry university research" achieved important results from 2019 to 2021, consistent with the recovery trend of the number of documents issued, as mentioned above. For example, Chen Yufen [2] used the social network analysis method

to quantitatively analyze the characteristics of an industry–university research cooperative innovation network and its impact on innovation performance from two aspects: different stages and different industries. Guided by the vision of science and technology development in 2035, Ren Xingxin [3] discussed a feasible path to realize the effective combination of industry, university, and research by 2035, by dissecting Bi Yusui, Professor of Shandong University of Technology, and his team's research and development of "chlorine free fluoropolyurethane new chemical foaming agent". In the literature, a cluster of the keyword "innovation" first appeared in Jiang Zhengguo's [4] *Research on the Innovation of Teaching Operation Mechanism under the Background of Industry University Research Cooperative Education in Newly Built Local Undergraduate Colleges* in 2011. In the same year, the clustering results began to increase and the research intensity also gradually increased. Results in the literature on the clustering of the keyword "universities" first appeared in Huang Yanfei's *An Analysis of the Ways to Form the Advantages of Independent Innovation of University Official Industry Research University Cooperation—Taking the Universities in the Yangtze River Delta as an Example* in 2011 [5]. The clustering results began to increase from 2011, but on the whole, the intensity of the three clusters decreased with the passage of time. At the same time, it can be seen from the emergence chart that the emerging keyword from 2015 to 2021 is "innovation performance"; from 2018 to 2021, the emergent keyword is "evolutionary game"; and from 2019 to 2021, the term "industry university research" emerged, and the emergence rate of these three terms has continued to this day, which shows that these three keywords represent the main development trend of domestic university research cooperation policy research.

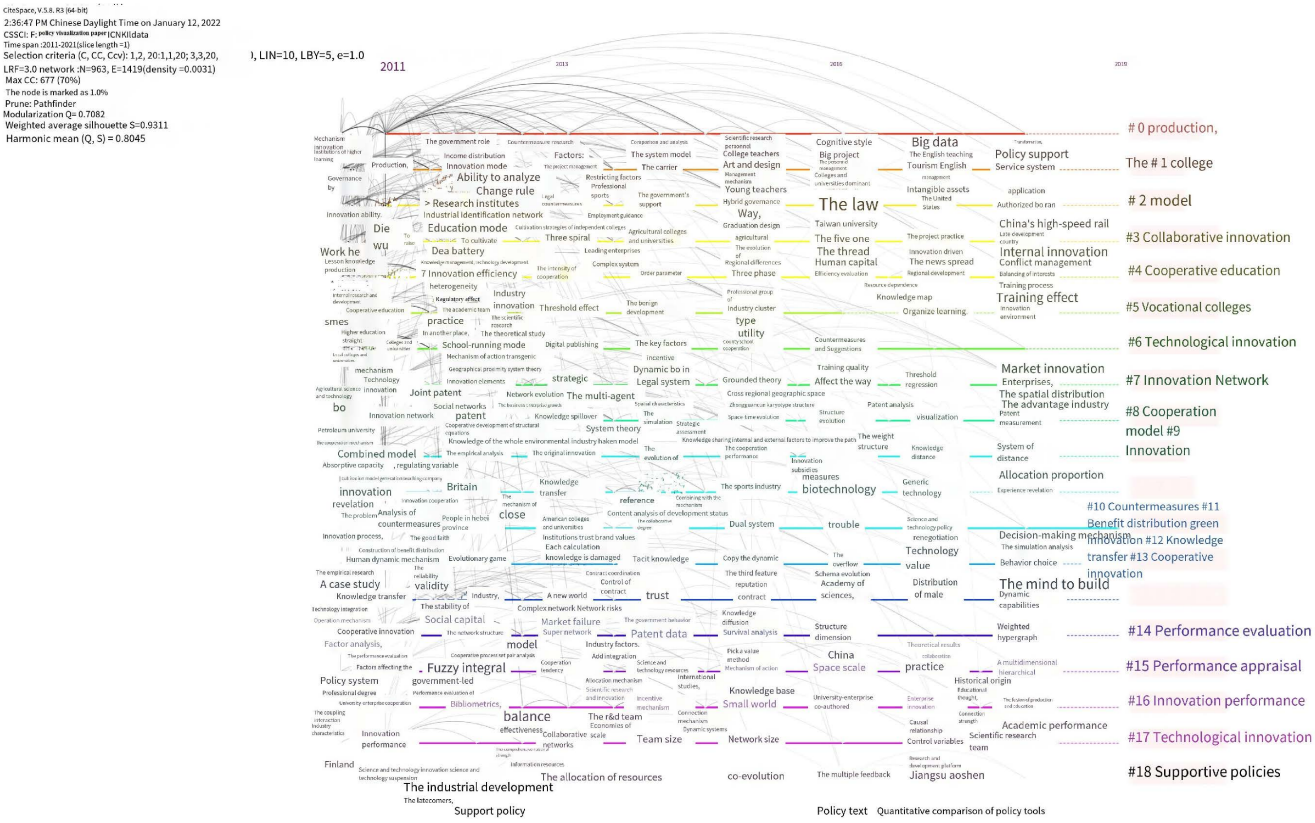


Figure 8. Keyword timeline of industry–university research cooperation policy research.

With the continuous development of the economy alongside science and technology, innovation performance, evolutionary game, and industry university research will continue to become hotspots of future research.

Figure 9. Keywords of industry–university research cooperation policy research.

In the era of the knowledge economy, open innovation has gradually become an important way for enterprises to obtain the key resources needed for technological innovation. Under the open innovation paradigm, the organizational boundary is no longer closed, and the innovation resources inside and outside the organization can complement each other. R&D activities are no longer limited to within the organization. Enterprises can reduce the uncertainty of technological innovation in the market by carrying out cross-organizational cooperation. From the perspective of forms of knowledge, the knowledge of enterprises, university research institutions, and scholars is heterogeneous and complementary. Therefore, enterprises will spontaneously carry out R&D cooperation with universities and research institutions according to their own interests and demands. However, with the increase in the degree of open innovation, enterprises will also face many problems, such as excessive searching, high transaction costs, difficult cooperative management, insufficient knowledge absorption capacity, and leakage of technical knowledge. As a result, open innovation may have a negative impact on enterprise innovation performance. Therefore, in the process of technological innovation, the relationship between the openness of cross-organizational cooperation and innovation performance is complex [6]. In the future, the research on innovation performance will become increasingly popular. In the process of inter-organizational cooperation, the impact of technological factors on industry–university research cooperation needs to be fully considered. Therefore, the game payment matrix of industry–university research cooperation innovation based on technological maturity and technological innovation is constructed. The equilibrium solution of industry–university research cooperation innovation is obtained by the evolutionary game method. Through numerical and case analysis, the impact of different changes in technological maturity and technological innovation on the willingness of industry–university research cooperation innovation is explored. Judging the technical reasons affecting the willingness of industry–university research cooperation innovation, evolutionary game theory plays an important role in the transformation of industry–university research achievements and the improvement of enterprise innovation performance [7]. Therefore, it will also exist in the future as a research hotspot.

In addition, we used the CiteSpace software to extract the keywords from the literature and create the keyword time zone map, in order to reflect the research content of this topic changing with time, and then observed the research trend in a certain time period. We set the top n of the selection criteria to 10 and the thresholds of C, CC, and CCV to 3, 3, and 20; 3, 3, and 20; and 3, 3, and 20, respectively. We obtained a keyword time zone map of industry–university research cooperation policy research (Figure 10).

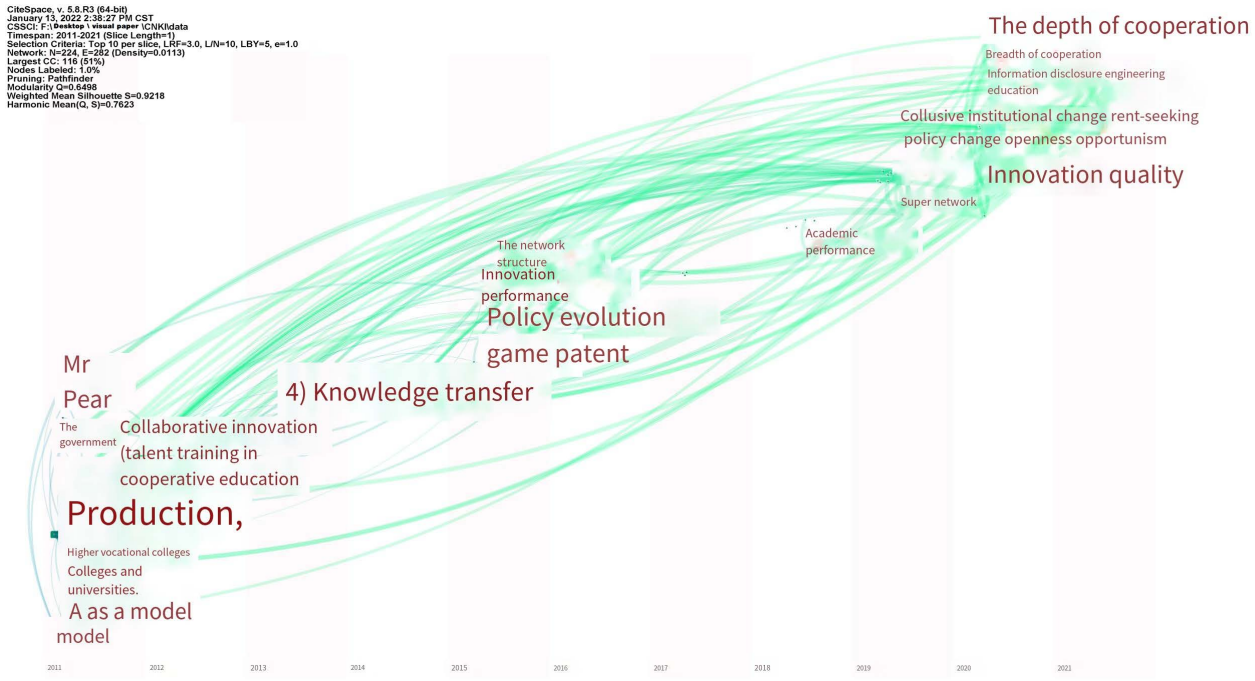


Figure 10. Keywords time zone map of industry–university research cooperation policy research.

Based on the above research, it can be seen from the keyword time zone map that the focus and amount of attention differ by period. Observing the keyword distribution in the past two years, it can be found that the keywords "cooperation breadth", "cooperation depth", "information disclosure", "collusion", "rent-seeking", "opportunism", and "innovation quality" appear in the time zone map in 2020; the keywords in 2021 include "engineering education", "institutional change", and "policy change". Therefore, it can be concluded that the future research trend of industry–university research cooperation policy research can be roughly divided into three parts.

The first part is "the comprehensive deepening of industry–university research cooperation". Liu Feiran, Hu Lijun, Fan Xiaoqun [5], and others analyzed and tested the impact of industry–university research cooperation on enterprise innovation quality based on the data of nearly one million patent applications of Chinese listed companies from 2005 to 2008, and concluded that the breadth of enterprise participation in industry–university research cooperation has an inverted "U"-shaped impact on innovation quality, and the depth of cooperation has a continuous positive impact on innovation quality. Gao Xia, Cao Jieqiong, Bao Lingling [8], and others used the jointly authorized patent data of China's ICT industry from 1999 to 2015, and extracted a large sample of panel data from 14,596 enterprises. Using the negative binomial regression model, they concluded, in terms of the two dimensions of cooperation breadth and depth, that universities play an important role in improving the innovation performance of China's ICT enterprises, followed by scientific research institutions. This proves the importance and necessity of research in the direction of cooperation breadth and depth when studying industry–university research cooperation policy.

The second part is "industry–university research cooperation and innovation performance". Qiu Yangdong [9] discussed the innovation incentive effect of the combination of industry, university, and research from the three dimensions of state ownership, market orientation, and intellectual property protection, and found that the cooperation of industry, universities, and research has a significant effect on the quantity and quality of enterprise innovation. It was proposed that, in order to improve the innovation performance and ensure innovation quality, we should actively promote market-oriented reform and the construction of an intellectual property protection system, so as to effectively improve the innovation performance of industry, university, and research cooperation. It can be

seen that innovation performance will become the direct purpose of industry–university research cooperation policy, which will maintain an important position in the field of industry–university research cooperation policy research.

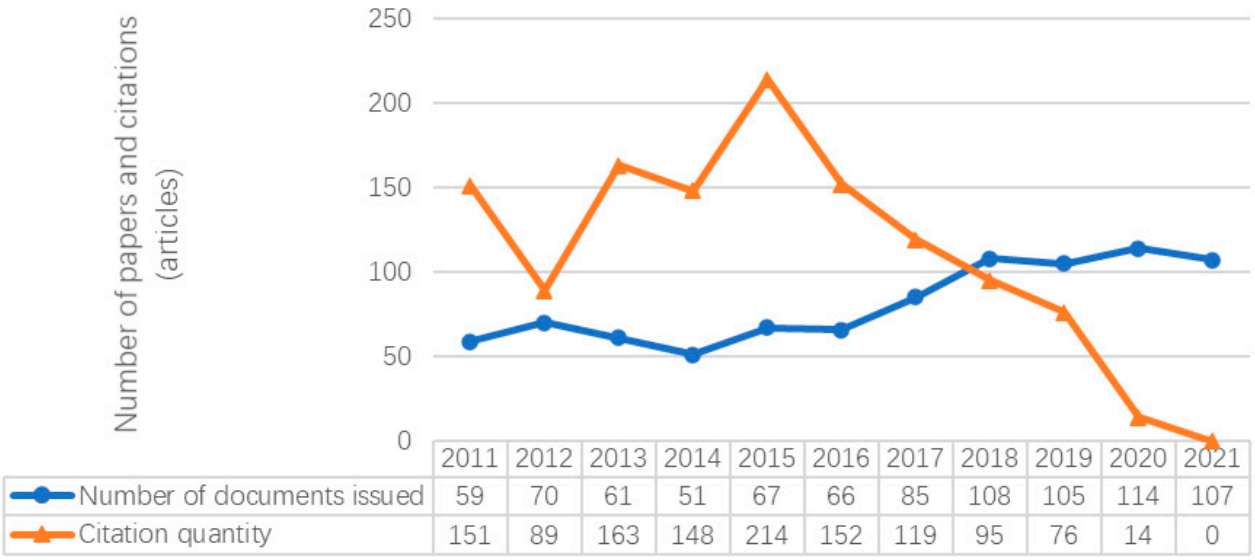
The third part is "the change of industry–university research cooperation policy". Peng Lin and Brent Jesiek [10] studied the changes in cooperative education policy in the United States and obtained the logic of the changes to the cooperative education policy structure and the historical changes to cooperative education policy in the United States. In terms of background and policy variables, the complexity of society is becoming increasingly prominent, and the top-level design, policy structure, informal institutional factors, and market forces have put forward new demands for cooperative education policy. In addition, industry–university research cooperation policy is at the key node of recovery, so under the theme of industry–university research cooperation policy, the trend of policy change and institutional change is beyond a doubt, and it will also become a research hotspot of industry–university research cooperation policy in the future.

4. Research Status of Industry–University Research Cooperation Policy Abroad

The above provides a knowledge map analysis of the research on domestic industry–university research cooperation policy, and then takes the literature collected by WOS as the source of data to perform statistical and trend analysis on the research of foreign industry–university research cooperation policy. The goal is to have an overall and directional grasp, so as to enlighten the follow-up research of industry–university research cooperation policy.

4.1. Issuance of Policy Research on Industry–University Research Cooperation

As can be seen from Figure 11, foreign research on the policy of industry–university research cooperation is relatively stable, and the number of documents issued generally shows a slow upward trend year by year, breaking through the annual number of 100 in 2018. Relatively speaking, the number of citations shows a very unstable trend. The number of citations shows three stages from 2011 to 2021: a stage of decline from 2011 to 2012, a recovery stage from 2013 to 2015, and a stage of continuous decline from 2016 to 2021. This indicates that foreign research on industry–university research cooperation policy has increased steadily on the whole, but research hotspots have been greatly updated and changed during this period, which has affected the stability of citation data. This shows that the research trend of industry–university research cooperation policy abroad is broader, and the research hotspot is more cutting-edge.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of documents issued	59	70	61	51	67	66	85	108	105	114	107
Citation quantity	151	89	163	148	214	152	119	95	76	14	0

Figure 11. Publishing and citation trends of policy research on industry–university research cooperation.

In terms of countries issuing documents for policy research on industry–university research cooperation, this paper screened the top ten countries (Figure 12). The United States was the first country to realize the combination of industry, university, and research. Its industrialization and modernization have attracted worldwide attention. In particular, the great achievements of the "Silicon Valley model" have attracted a wave of research cooperation among countries. The first countries to study the policy of industry–university research cooperation are also countries that have enjoyed the results of industry–university research cooperation in advance. Among the top ten countries, there are eight European and American countries, one Asian country, and one Oceanian country. It can be seen that European and American countries have certain leading advantages in this research topic. Secondly, it can be seen that the research on industry–university research cooperation policy is generally paid more attention all over the world, and the scope of research subjects is broad.

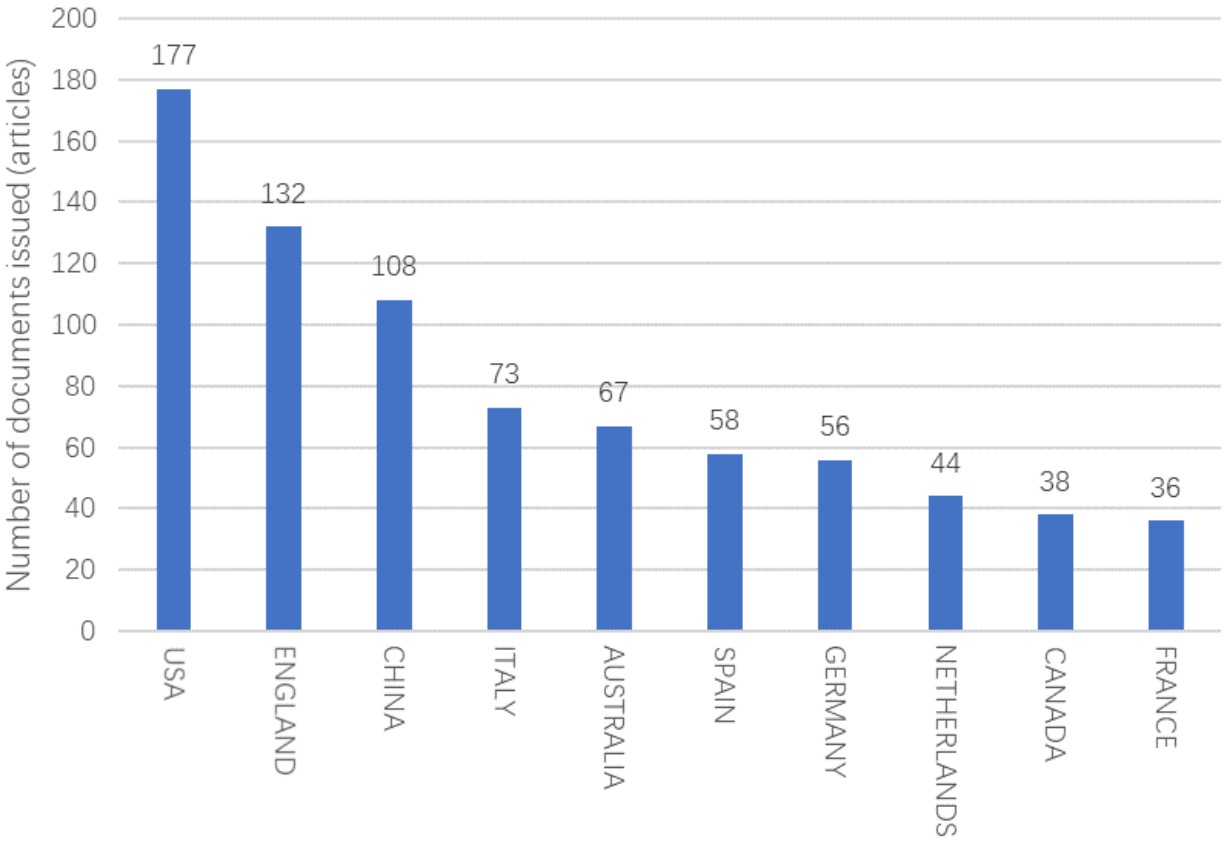


Figure 12. National distribution statistics of industry–university research cooperation policy research.

We ran the CiteSpace software, set the node type as the mechanism, and obtained the number of nodes, n = 310, the number of connections, e = 190, and a density of 0.004. Among them, the network modularization evaluation index, q = 0.8991, the author's collinear network knowledge map (see Figure 13), and the Q value, which tended to be 1, indicating that the network clustering effect of the research content in the map is good. As can be seen from the figure, there are roughly six cooperative groups. Among them, the largest is the cooperation network centered on the Technical University of Valencia in Spain, which is also the most central point in the whole analysis. The second is the cooperation network centered on the Georgia Institute of Technology, Canadian Immigration Consultant Industry Association, London Berkeley University, European Commission, and Copenhagen Business School. The Georgia Institute of Technology has close cooperation with the Chinese Academy of Sciences and Beijing University of Technology. What is quite different from what was found in China is that most of the relevant research networks abroad have relatively close research cooperation. It can be seen

that international cooperation is one of the important conditions for the progress of policy research on industry–university research cooperation. More schools and institutions will cooperate and exchange knowledge in the future.

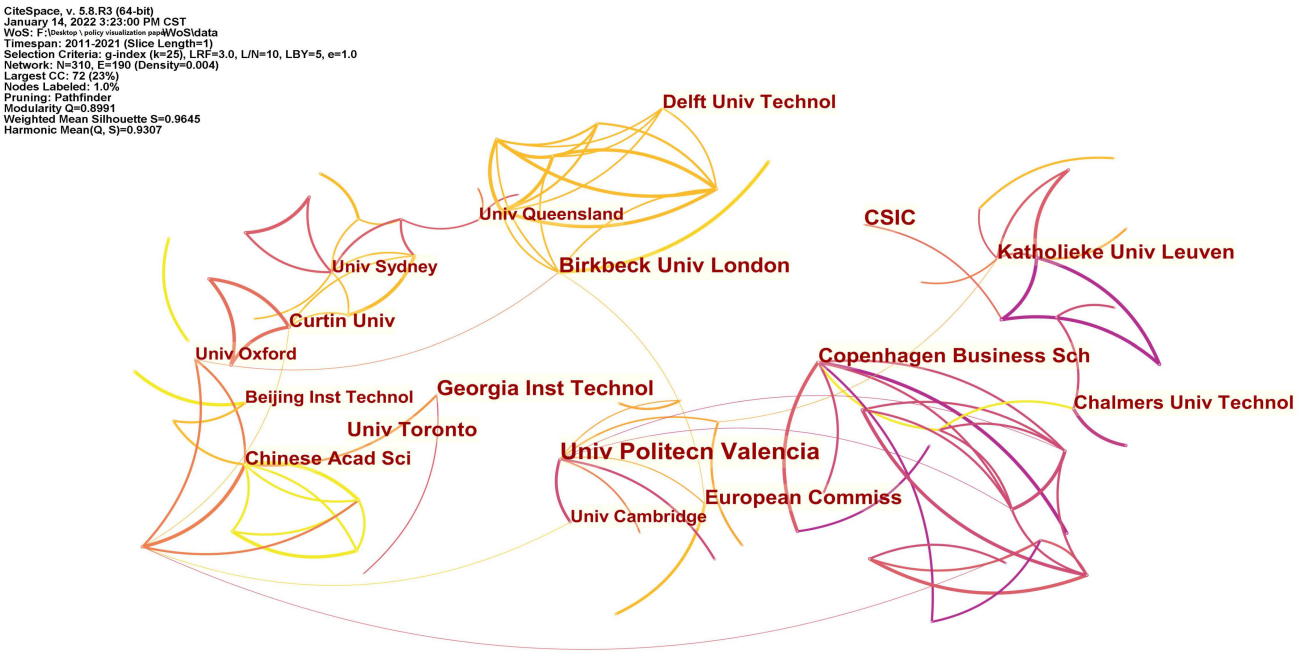


Figure 13. Institutional cooperation network of industry–university research cooperation policy research.

Similarly, under the operation of CiteSpace, the top 10 WOS categories in the policy research direction of foreign industry–university research cooperation (see Table 4) were selected, including economics, engineering, environmental science and ecology, public management, pedagogy, and other disciplines. The characteristics of foreign policy research on industry–university research cooperation are dominated by the social sciences, including 408 papers on economics, accounting for 45.69% of the total literature. At the same time, natural disciplines such as engineering and ecology also account for a certain number of papers. It can be seen that interdisciplinary research is obvious and there are many interdisciplinary disciplines. From the perspective of natural science and social science, the research on industry–university research cooperation policy abroad is more prominent in natural science, which shows that the improvement of the theoretical research level is conducive to the development and application of practical technology.

Table 4. Discipline direction statistics of industry–university research cooperation policy research.

Research Type	Number of Documents Issued (Articles)	Proportion of Documents (%)
Business And Economics	408	45.69
Social Science Citation Index (SSCI)	243	27.21
Management We Social Science Citation Index (SSCI)	214	23.96
Engineering	158	17.69
Environmental Sciences And Ecology	150	16.80
Engineering, Industrial	111	12.43
Business	101	11.31
Public Administration	90	10.08
Science And Technology—Other Topics	90	10.08
Education And Educational Research	74	8.29

4.2. Authors of Policy Research on Industry–University Research Cooperation

After importing the data into CiteSpace, the author was selected as the node type. According to statistics, the number of authors of foreign industry–university research cooperation policy research from 2011 to 2021 was 2618, with an average of 2.93 authors per article. Table 5 reflects the author statistics of the top 10 high-frequency citations generated after the operation of CiteSpace software. Among the six articles cited by Alessandro Musi [11], *The Effects of University Rules on Spinoff Creation: The Case of Academy in Italy* has been cited 53 times, which is a highly cited work in the literature and an important research achievement in this research field. At the same time, there are four Chinese scholars in this book. It can be seen that China's research level and quality have been recognized by foreign academic circles.

Table 5. Industry–university research cooperation policy research; high-frequency author citation statistics.

Serial Number	Cited Quantity (Times)	Author
1	6	Alessandro Muscio
2	4	Pablo D'Este
3	3	Anders Brostrom
4	2	Alastair M Buchan
5	2	Hua Cheng
6	2	Carolin Plewa
7	2	Bojun Hou
8	2	Hiroyuki Okamuro
9	2	Heng Chen
10	2	Jin Hong

Using CiteSpace, the author cooperation network diagram of industry–university research cooperation policy research with a number of nodes, n, of 301; a number of connections, E, of 101; and a density of 0.0022 is obtained (see Figure 14). As can be seen from the figure, there are three large-scale cooperation networks and six small cooperation networks. Among them, the largest is the cooperation network centered on Pablo d'Este. The second is the cooperation network centered on Zhi Yang and Negin Salimi. Thirdly, small cooperative networks and personal research also exist. It can be seen that there are a large number of individual nodes. This mainly shows that foreign countries are in a loose stage of cooperation in this research field, the awareness of communication and exchange in the field is weak, and the cooperation between academic researchers needs to be strengthened.

4.3. Literature on Important Nodes of Policy Research on Industry–University Research Cooperation

We imported the literature data downloaded by WOS into CiteSpace software for CO citation analysis. The node type was selected as the reference; the time span was 2011-2021; the time slice was set as 1 year; and other settings were kept at their default. According to Figure 15 and Table 6, d'Este and Laursen are the earliest among the 10 key node documents of industry–university research cooperation policy research. D'Este [12] mentioned in *Why do Academics Engage with Industry? The Entrepreneurial University and Individual Motivations* initiatives that, in order to explore the reasons for "academic participation in industry", according to the comprehensive survey data of researchers in physics and engineering, show that most scholars contact the industry for further research, not the so-called commercialization of knowledge. Therefore, the following conclusions are drawn: the government should avoid industry participation focusing on monetary incentives, and consider a broader in-

centive mechanism to promote the interaction between academia and industry. In *Exploring the Effect of Geographical Proximity and University Quality on University Industry Collaboration in the United Kingdom*, Laursen [13] focused on the impact of geographical proximity and university quality on school enterprise cooperation. The research results show that proximity to a lower-level university will reduce the tendency of enterprises to cooperate locally. On the contrary, proximity to a higher-level university will increase the tendency toward cooperation. In other words, enterprises prefer the research quality of university partners rather than their geographical proximity. In *Academic Engagement and Commerce: a Review of the Literature on University Industry Relations*, Perkmann [14] systematically reviewed the research on various activities between academic scientists and enterprises, defined it as "academic participation", determined the antecedents and consequences of "academic participation" among individuals, organizations, and institutions, and then compared the findings with the antecedents and consequences of commercialization. Finally, the future research needs, opportunities for method improvement, and intervention policies are determined. Then, Bozeman [15] made a critical overview of the literature in *Research Cooperation in Universities and Academic Entrepreneurship: The State-of-the-Art*, and put forward some suggestions for improving cooperative research: pay more attention to multi-level analysis and its interaction; pay more attention to the measurement of impact than output; conduct more research on "misconduct" in cooperation, including exploitation; and pay more attention to the motivation of collaborators and the social psychology of cooperative teams.

Figure 14. Author cooperation network of industry–university research cooperation policy research.

With the gradual deepening of the research on the policy of industry–university research cooperation, Rasmussen [16] also conducted novel research in *The Influence of University Departments on the Evolution of Entrepreneurial Competences in Spin-off Ventures*, revealing how the professional background of the university affects the development at the initial stage of the formation of University derivative enterprises, and proposing that in order to better understand the establishment and development of new enterprises based on technology, more attention should be paid to capacity development at the department level within universities. Meanwhile, Siegel [17] also published *Academic Entrepreneurship: Time for a Rethink?*, which clarifies the viewpoint of "academic entrepreneurship", that is, the university's efforts to promote commercialization on campus and around the university, and found that great changes have taken place in recent years. Therefore, it

is pertinent to judge and reflect on "academic entrepreneurship", and point out that the theoretical and empirical research of "academic entrepreneurship" must take these changes into account, so as to improve the preciseness and relevance of future research on this topic. In terms of the requirements of universities and the changes in the comprehensive external environment, it can be seen that the theory and practice in this research field are gradually improving and developing. Relatively speaking, Ankrah [18] said in the article *Universities Industry Collaboration: a Systematic Review* that it is an indisputable fact that the cooperation between universities and industries is increasingly regarded as a tool to promote innovation through knowledge exchange, but the description of this knowledge system suffers from a lack of effective comprehensive views; hence, the author adopted a systematic procedure to review the literature on university–industry cooperation, and extracted several research approaches through the comprehensive analysis of the literature status. Guerrero [19] set out from the perspective of endogenous growth in his article *Economic impact of entrepreneurial universities' activities: an exploratory study of the United Kingdom*, in which the proposed conceptual model was tested using data collected from 147 universities in 74 regions of the UK, from 2005 to 2007. The results show the positive impact of teaching, research, and entrepreneurial activities on the economy, especially knowledge transfer. This shows the positive role of the students produced by industry–university research cooperation.

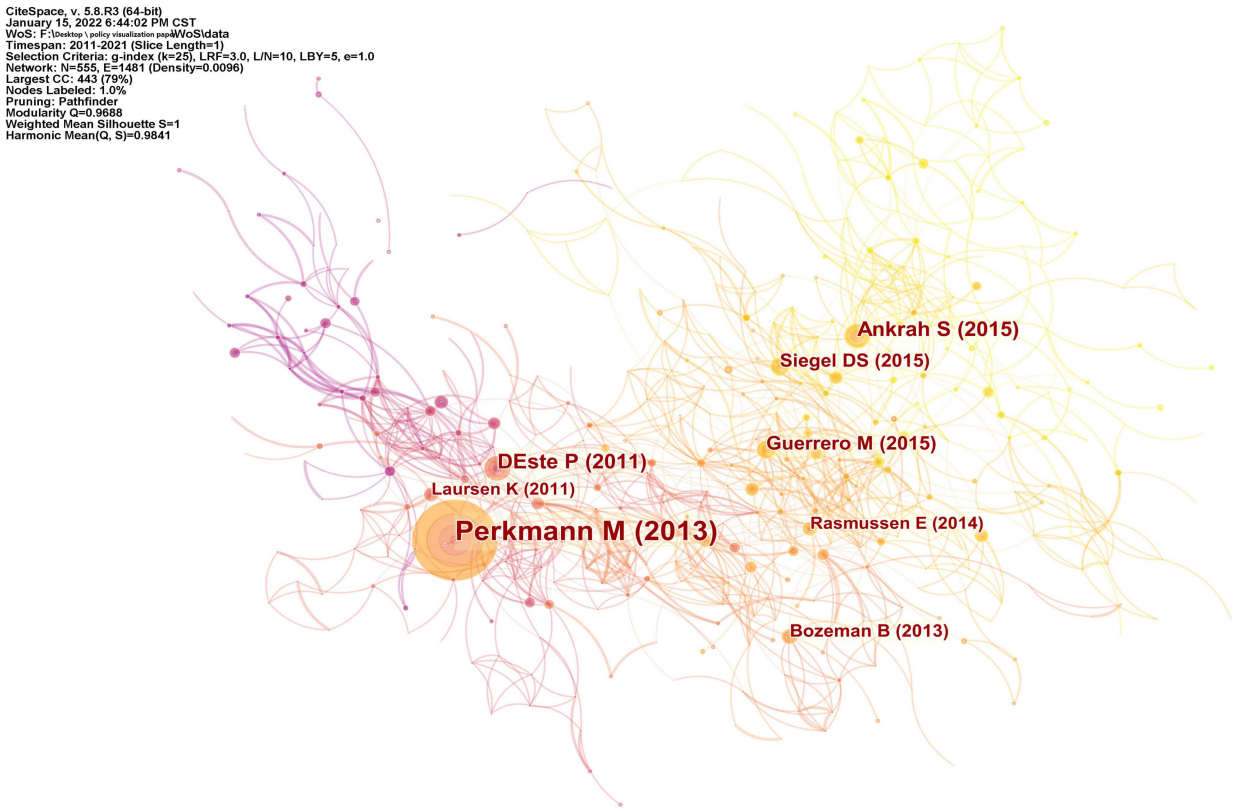


Figure 15. The literature on the policy research of industry–university research cooperation has been cited online.

4.4. Topical Issues of Policy Research on Industry–University Research Cooperation

There were 5527 keywords in the retrieved literature, with an average of 5.85 keywords per article. The top 20 high-frequency keywords were selected according to the word frequency list produced using CiteSpace (see Table 7). The word with the highest frequency was industry, followed by innovation, performance, and university, which represent the core of the research. In addition, the focus of foreign research on industry–university

research cooperation policy is relatively uniform, being embodied in keywords such as knowledge, research and development, policy, technology transfer, science, and impact.

Table 6. Literature on key nodes of industry–university research cooperation policy research.

Serial Number	Author	Document Name	Year of Publication	Times Cited
1	Perkmann M	Academic engagement and commercialization: A review of the literature on university–industry relations	2013	61
2	D'Este P	Why do academics engage with industry? The entrepreneurial university and individual motivations	2011	19
3	Ankrah S	Universities–industry collaboration: A systematic review	2015	19
4	Guerrero M	Economic impact of entrepreneurial universities' activities: An exploratory study of the United Kingdom	2015	15
5	Siegel DS	Academic Entrepreneurship: Time for a rethink?	2015	14
6	Bozeman B	Research collaboration in universities and academic entrepreneurship: The state-of-the-art	2013	12
7	Laursen K	Exploring the effect of geographical proximity and university quality on university–industry collaboration in the United Kingdom	2011	11
8	Rasmussen E	The influence of university departments on the evolution of entrepreneurial competencies in spin-off ventures	2014	11

Table 7. Industry–university research cooperation policy research; high-frequency keyword statistics.

Serial Number	Keyword	Word Frequency (Times)	Serial Number	Keyword	Word Frequency (Times)
1	industry	185	11	triple helix	78
2	innovation	176	12	knowledge transfer	75
3	performance	145	13	technology	66
4	university	133	14	firm	65
5	knowledge	130	15	collaboration	61
6	research and development	130	16	commercialization	60
7	policy	119	17	system	48
8	technology transfer	113	18	higher education	47
9	science	106	19	absorptive capacity	45
10	impact	101	20	management	45

In CiteSpace, the node type was set as keyword; the time span was 2011–2021; the time slice was set as 1 year; and other factors were kept at their default settings. After running the process, the keyword clustering view using the LLR algorithm was obtained (see Figure 16). In the figure, there are 417 nodes, 1653 connections, and the clustering network density is 0.0191. The Q value of the clustering module is 0.4419, greater than 0.3, and the s value of the clustering average contour is 0.7144, greater than 0.7, which means that the clustering structure is significant and the clustering effect is convincing.

After forming the timeline (see Figure 17), the first seven clusters are partnership, university industry collaboration, technology transfer, public health, knowledge transfer, university industry linkages, and science policy. The occurrence time of keywords under the first cluster is discussed in *R&D Productivity and the Organization of Cluster Policy: an Empirical Evaluation of the Industrial Cluster Project in Japan*, published by Nishimura in April 2011, since, in the same year, the clustering results began to increase. Combined with the list of keywords (see Figure 18), the university industry linkage increased rapidly from 2018–2019. Similarly, the amount of attention paid toward the business model suddenly increased from 2018–2019, which attracted further attention. Over time, the research of this clustering has been maintained at a high level. There are also two special clusters. One is the research policy, which began clustering in 2012. The first is Limingliang's *The Role*

of Chinese Universities in Enterprise University Research Collaboration, which has attracted continuous attention. Another cluster is regional development, which first appeared in 2011. The first document is Villasana's *Founding University Industry Interactions under a Triple Helix Model: The Case of Nuevo Leon, Mexico*. Since 2011, the number of clustering results has increased. Relatively speaking, sustainability began to emerge in 2017 and ended in 2018. In the same year, clustering became colder, attention decreased, and clustering stopped in 2019.

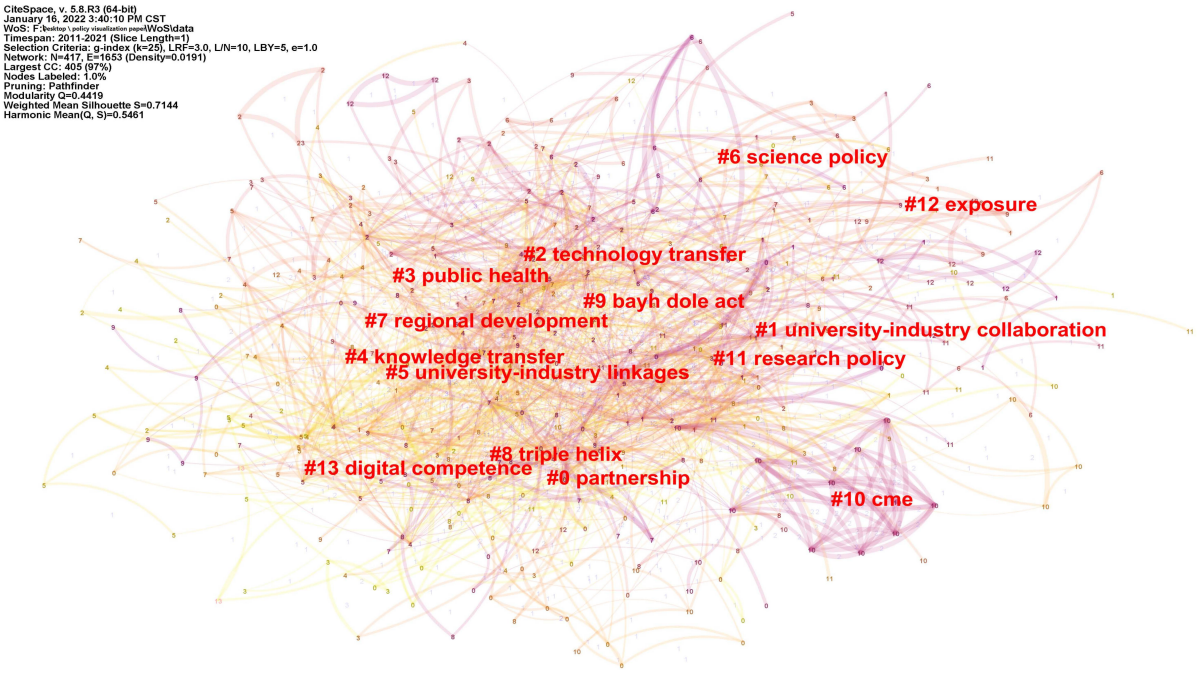


Figure 16. Keyword clustering of industry–university research cooperation policy research.

Top 18 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2011–2021
united states	2011	4.03	**2011**	2014	
spillover	2011	2.84	**2011**	2013	
network	2011	3.29	**2012**	2015	
us	2011	2.79	**2012**	2013	
firm	2011	2.83	**2013**	2014	
academic entrepreneurship	2011	2.55	**2014**	2018	
link	2011	3.18	**2015**	2016	
work	2011	2.65	**2015**	2016	
transfer office	2011	3.31	**2016**	2019	
sustainability	2011	2.72	**2017**	2018	
experience	2011	2.69	**2017**	2018	
open innovation	2011	3.04	**2018**	2019	
uk	2011	2.68	**2018**	2021	
business model	2011	2.54	**2018**	2019	
university-industry linkage	2011	2.54	**2018**	2019	
framework	2011	3.12	**2019**	2021	
quality	2011	2.75	**2019**	2021	
education	2011	2.72	**2019**	2021	

Figure 17. Keywords timeline of research of industry–university research cooperation.

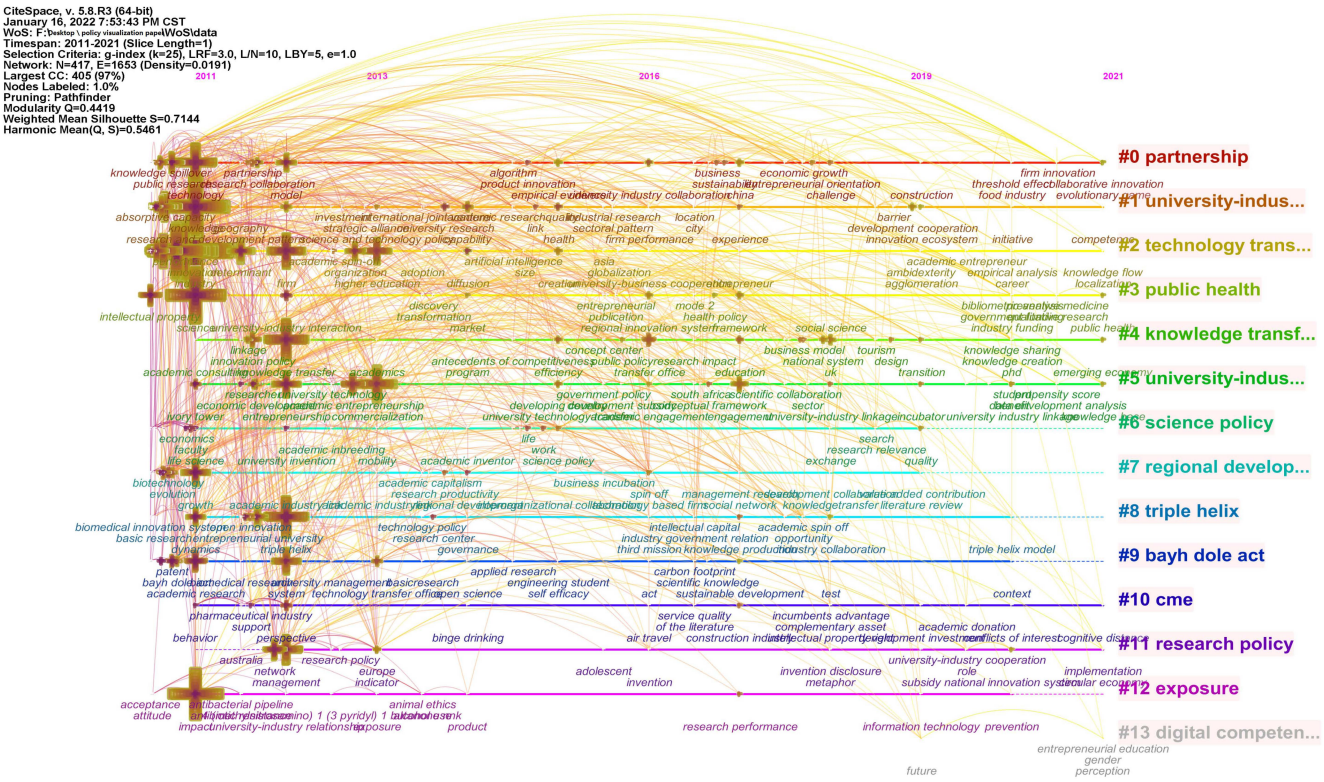


Figure 18. Keywords of industry–university research cooperation policy research.

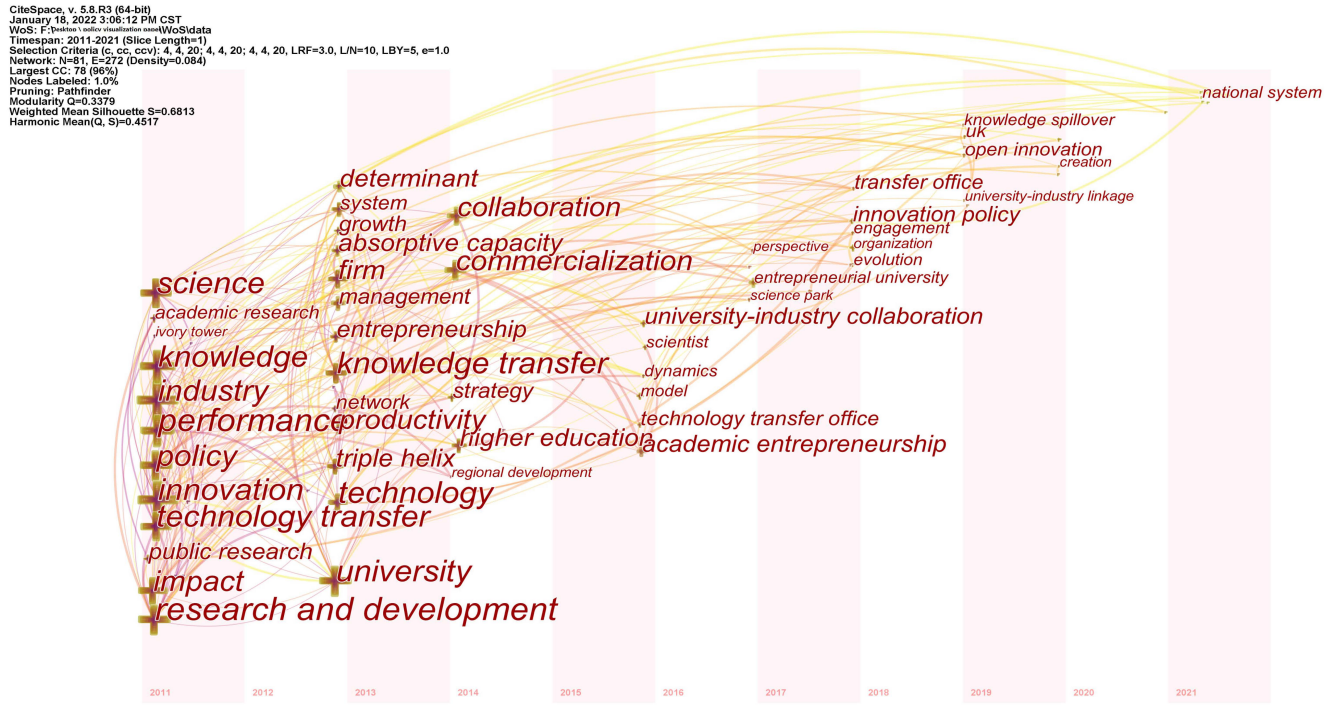


Figure 19. Keywords time zone map of industry–university research cooperation policy research.

According to the trend in the research and development of foreign countries from 2011 to 2021, the clustering nouns represented by technology transfer and knowledge transfer have maintained high popularity since their rise. It can be seen that foreign countries are in a leading position in the transfer and application of research results, which is confirmed by the excellent results of foreign industry–university research cooperation. Foreign countries

have paid increasing amounts of attention to research policy and other negative aspects since 2012. Combined with the attention performance of the framework from 2019 to 2021, as shown in the figure, the industry–university research cooperation policy will take the macro policy design as one of the research priorities in the future against the background of a changing social environment. At the same time, according to the number of emergent keywords from 2019 to 2021, relevant foreign research will continue in a stable trend.

Combined with the cluster view and the time zone map of industry–university research cooperation policy research (see Figure 19), the foreign industry–university research cooperation policy research in recent years can be divided into two parts: research on scientific research institutes and research on production enterprises.

The research on scientific research institutes mainly includes achievement transformation, knowledge innovation, and research patents. Cheng, Hua [20] and others discussed this in the article *The Effect of University Industry Collaboration Policy on Universities' Knowledge Innovation and Achievements Transformation: Based on Innovation Chain*. Based on the calculation of China's provincial and ministerial policies, they studied the impact of industry–university research cooperation policy (UIC policy) on university knowledge innovation and achievement transformation. The results show that UIC policy has a significant positive impact on school enterprise cooperation investment and government school cooperation investment; the relationship between UIC policy and knowledge output, and the relationship between UIC policy and achievement transformation, are inverted-U-shaped. Tolstykh, Gamidullaeva, and Shmeleva [21] believe that universities play a vital role in the innovation ecosystem, especially in the interdisciplinary nature of modern innovation and the implementation of interdisciplinary projects. They also introduce the methods to realize the function of an interdisciplinary ecosystem integrator, which is the "entry point" for creating new ideas, new capabilities, and new technology solutions, and developing and testing new technology projects. Murgia [22] found that there is a gap in the literature on how universities build and maintain their R&D cooperation. Therefore, by analyzing the tendency of Italian universities to reiterate joint patent applications with other organizations, and conducting multi-level modeling, the importance of cooperation diversity in further joint patent development was confirmed.

The research on production enterprises mainly includes industrial support policy, technology commercialization, and cooperation trust. Vlasova [23] conducted an empirical analysis based on the results of a professional survey of high-tech and medium-high-tech manufacturing enterprises with active innovation in Russia in 2018, and relied on the concept of "additivity". The research results show that enterprises interacting with R&D execution organizations are more likely to receive public support, but the support provided will rarely lead to significant changes in their performance. Therefore, the cooperation between R&D institutions and universities seems to be mainly related to the general improvement of enterprise competitiveness. Meijer, Huijben, van Boxstael, and Romme [24] identified the obstacles and driving factors for the technology commercialization of small and medium-sized enterprises, mainly including management, finance, technology and policy, by combining a literature review with exploratory case studies of 20 small- and medium-sized enterprises in the field of sustainable energy in the Netherlands. Bellini, Piroli, and Pennacchio [25] analyzed the driving forces and benefits of university industry cooperation from the perspective of enterprises; used a structural equation model to examine the data collected from a sample of Italian small- and medium-sized companies engaged in the field of information and communication technology; and concluded that enterprises should develop strategic capabilities to fully benefit from cooperation with universities. From a policy perspective, it was concluded that efforts need to be made to establish channels and tools to enhance trust between industry and universities, especially to support small enterprises.

5. Conclusions

Through the above research, we can draw the following conclusions.

First, in terms of time and research progress, the research on industry–university research cooperation policy at home and abroad is roughly the same. Foreign research started in the 1960s and 1970s, and domestic research started slightly later. However, with the increase in domestic investment and policy support, there was no big gap remaining between domestic and foreign theoretical research and achievements by the early 21st century. After experiencing the cooling off period of overheated development, China has shown recovery and development in recent years, which is consistent with the steady development trend abroad.

Second, the research topics are roughly the same, and the concerns are slightly different. At present, the research directions at home and abroad are generally similar, involving academic entrepreneurship, open innovation, etc. The difference is that China pays more attention to the research of colleges and universities, and uses industry–university research cooperation as a mechanism for cultivating innovative talents, improving scientific research, and enhancing social services, while foreign countries pay more attention to the technological utilization and technological innovation of enterprises and their accompanying economic interests. This has much to do with the states of socialism and capitalism. However, in recent years, China has gradually emphasized performance evaluation and innovation performance. It can be seen that on the basis of introducing and learning foreign experiences, China has gradually established and developed a research trend in line with Chinese characteristics.

Third, the theoretical system of industry–university research cooperation policy research needs to be deepened. At present, the research on the policy of industry–university research cooperation is mostly divided into two parts: scientific research institutes and production enterprises. There is a lack of exploration of the relationship between the two and their sustainable cooperation, which shows that the empirical theoretical systematic research is not sufficiently deep and comprehensive, and there is no systematic theory and method.

From this point of view, in the future, China's domestic policy research on university research cooperation needs to make breakthroughs in the following aspects.

First, it is closely related to the functions of colleges and universities, the nature of enterprises, and social needs. In future work, we need to verify the dominant position in the process of industry–university research cooperation, clarify the primary function of ensuring the education of colleges and universities, and improve the enthusiasm of enterprises to participate in cooperation. The social environment should be supported by certain policies. The research must first ensure the correctness and stability of the overall direction.

Second, we must attach great importance to empirical research. The field of industry–university research cooperation policy involves multiple unit subjects, and the variable nature of the unit subjects is very obvious. Each instance of cooperation between different types of universities and enterprises in different industries has unique characteristics, so a successful case of industry–university research cooperation cannot be directly applied to another. It can be seen that such research must emphasize the connection with the actual situation, and must be combined with lessons drawn from field practice, so as to provide correct and reasonable theories and methods for the development of future research and practical work.

Third, we must pay attention to cross-organizational research. At present, there is a phenomenon of disconnection between universities and enterprises, and between natural science and social science in the research of industry–university research cooperation policy. Some innovative scientific research achievements have not been applied in practice to the greatest extent due to the lack of appropriate guidance in the social sciences. This leads to the field gap between research results and production demand. Therefore, in the process of policy research on industry–university research cooperation, we must understand the

multi-party main factors in the field to realize the efficient operation of industry–university research cooperation.

Author Contributions: J.L. and X.S. designed and wrote the paper; X.D. and B.L. supervised the paper writing; J.Z. and X.S. collected and collated materials and performed field data collection. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Hebei Social Science Foundation Project "Research on the implementation of policies to curb agricultural land conversion in the development of new agriculture in Hebei Province" (Grant No. HB19Gl015), and by the Hebei Provincial Department of Education Science Research Plan Project—a major research project of humanities and social sciences—"Research on the promotion path of industrial chain of Hebei coastal counties (districts and cities) from the perspective of coordinated development of Beijing, Tianjin and Hebei" (Grant No. ZD202104).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest: We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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