Analysis on the Evolution Path and Hotspot of Knowledge Innovation Study Based on Knowledge Map

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Abstract: Innovation is the main driving force for promoting high-quality economic development. The ability for knowledge innovation and knowledge transformation productivity reflects the ability for scientific research transformation and the comprehensive strength of the science and technology of the country. This paper takes the knowledge innovation literature collected in the Web of Science database as its research object, carries on the knowledge atlas analysis with Citespace IV software, makes a knowledge atlas of the space-time distribution, document co-citation and keyword co-occurrence, respectively, and further explores the distribution status, changing trend and hot areas of knowledge innovation research. (1) American and British scholars have led the research in knowledge innovation, and Chinese scholars have followed the international frontier in this field; (2) The research evolution path of knowledge innovation can be summarized as follows: the research object is gradually detailed from the macro-enterprise level to the micro-enterprise level. The research hotspots are as follows: (3) The four hotspots of knowledge innovation research are based on research on the knowledge innovation system within enterprises, research on the knowledge innovation mode based on innovation cooperation among enterprises, and research on the knowledge innovation among enterprises based on inter-organizational knowledge. Research on the knowledge innovation path of knowledge sharing and enterprise knowledge innovation development is based on the global strategic orientation. This paper clarifies the evolution path and development trend of knowledge innovation research, offering a summary for further research and motivating professionals to research future knowledge innovation.

Keywords: knowledge innovation; CiteSpace IV; knowledge map; evolution path; hot topics

1. Introduction

As we all know, science and technology are the foundation for a country to develop its comprehensive national strength, while innovation is the inherent requirement for technological improvement and the driving force for economic development. With the further development of globalization, countries and enterprises with breakthrough innovations can easily monopolize the global market and acquire capital during the process of development in the international area, in order to maintain the sustainable competitiveness of the country and enterprises. The ability for knowledge innovation and knowledge can be transformed into productivity, which reflects the country's level of scientific research and comprehensive science and technology. The knowledge-creating company: How Japanese companies create the dynamics of innovation [1] is a pioneering work in the field of knowledge innovation. Nonaka argued that short-term efficiency makes a sacrifice for knowledge

innovation activities, but that it will improve the long-term performance of the firm and then build a framework for knowledge innovation study. This theory has aroused great attention from academic scholars and the business sector in terms of the process of further development. Additionally, it has become one of the indispensable research directions in the field of innovation management.

Recently, there have been a lot of literature reviews and qualitative classification research on knowledge innovation research from a single perspective, such as some scholars focusing on the knowledge innovation system model [2–5], some scholars focusing on the ability for knowledge innovation [6–8], and other scholars focusing on the performance of knowledge innovation [9,10]. The scope of the literature is limited, and the amount of literature is limited. It can neither comprehensively and objectively reflect the whole picture of knowledge innovation study, nor systematically demonstrate the process of hotspot in knowledge innovation. Although these existing comments are invaluable to scholars in understanding the development of knowledge innovation, they rely primarily on qualitative methods to review the content and themes of the existing literature. However, more knowledge can be gathered from quantitative methods that can assess and track the development of this rapidly evolving literature. Similarly, our understanding of knowledge innovation research may benefit from the overview and evolution of quantitative literature. The quantitative visualization of the evolution of knowledge innovation is useful because it complements and validates the conclusions of scholars based on qualitative evaluations, as well as quantitatively demonstrating the way in which knowledge innovation is developed [11]. In this quantitative review, we can examine the profile and development of the knowledge innovation field and objectively and intuitively provide an overall overview. In addition, recent advances in visualization tools such as CiteSpace [12] provide a quantitative and rigorous tool for innovating research patterns and evolution patterns using big data visualization knowledge. In recent years, knowledge map tools have been used to visualize the bibliometric analysis of trends and to visualize trends in some special professional fields, which has become a hot topic for scholars and the academic field. There are many innovative management areas, such as open innovation [11], destructive innovation [13], and the innovation system [14] for which this has been used to acquire results. However, we have not found a literature pertaining to results related to the visualized bibliometric analysis of knowledge innovation research and hotspots. Therefore, it is important and timely to make a visual quantitative review of the prospect and development of knowledge innovation research. In this study, we attempt to quantitatively describe the overview and development trajectory of knowledge innovation research, and to find new research frontiers and emerging trends in knowledge innovation literature.

Therefore, this paper is based on the 1992 to 2019 database related to literature on the web of science. This paper uses the method of bibliometrics and the analysis of the visual tool, CiteSpaceIV, to use a statistical analysis and focus on the knowledge innovation research literature. Our bibliometric analysis contributes to knowledge innovation in a variety of ways. First, our research provides a new way to view the field of knowledge innovation and its relevance by examining common citations and co-occurring data. Then, we use bibliometrics to assess knowledge innovation research and visualize the prospects of knowledge innovation research. Second, we quantitatively track the evolution of knowledge innovation and its underlying theory from 1992 to 2019. For example, our research can show how the frontiers of knowledge innovation research are changing over time. Third, we will link the analysis of the evolution to a comprehensive future research agenda, which may help to generate new streams of knowledge innovation research. On the basis of a comprehensive summary of the time and space in terms of the distribution of journals that are related to knowledge innovation and according to the further development of the knowledge mapping as well as the frontiers and hotspots of knowledge innovation research, this paper clarifies the evolution path and development trend of knowledge innovation research, offering a summary for further research. Therefore, this article can help readers understand the frontier areas and emerging trends of knowledge innovation research. All in all, our research motivates professionals to research future knowledge innovation.

2. The Data Sources and Research Methods

2.1. The Data Sources

This paper uses the data source from Web of Science's SCI-E (Science Citation Index Expanded) database and SSCI (Social Sciences Citation Index) database to study related research on knowledge innovation. In order to eliminate misdetection and missing information during the process of searching, this paper is based on the classic literature and ideas from some professors and designs a reasonable formula for a logical relationship search to ensure that the results can cover the field as comprehensively as possible. The research results were acquired as shown in Table 1.

Table 1. The acquisition method of the research data.

| Search Settings	Content
Database	SCI-EXPANDED, SSCI
Search Method	TS = ("knowledge innovation") OR TS = ("knowledge management" AND innovation)
Literature	ARTICLE;REVIEW
Time Span	1992–2019
Time	2019/8/9
Results	2070
Number of Citations	75,773

2.2. Research Methods

The knowledge map is a kind of co-citation analysis and co-occurrence analysis method that presents the research hotspot, evolution process and trend of development in a certain research field, and it can have a visual form. It takes all the research literature as samples in a certain field over some time periods. Therefore, this method can visually reflect the research and development trends in the field of knowledge innovation. Then, this paper will use Citespace IV software to analyze knowledge innovation in the field of innovative areas. Citespace IV is a visual document analysis tool developed by Professor Chen Chaomei of Drexel University in the United States [12]. It can realize a co-citation analysis, co-word analysis and cooperation analysis among authors in relation to literature. This study mainly uses the reference citation analysis, keyword co-occurrence and cluster analysis, and the analysis of national institutions and authors, which can fully present the research structure, hotspots and frontiers in the field of knowledge innovation.

3. Space-Time Distribution of Literature on Knowledge Innovation

This section may be divided into subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. Research Methods

As shown in Figure 1, the research on knowledge innovation can be roughly divided into two stages, as follows. From 1992 to 2004, there was a stage of stable development. From 2005 to 2018, there was a stage of rapid development. In the previous stage, especially from 1992 to 2004, research results mainly came from the United States, Germany, Britain, Switzerland and the Netherlands, which laid the strong theoretical foundation for knowledge innovation. By 2018, the number of published articles had for the first time exceeded 200. The increasing amount of literature also shows that knowledge innovation has gradually become a hot topic in the field of innovation management due to the arrival of a knowledge economy in the world.
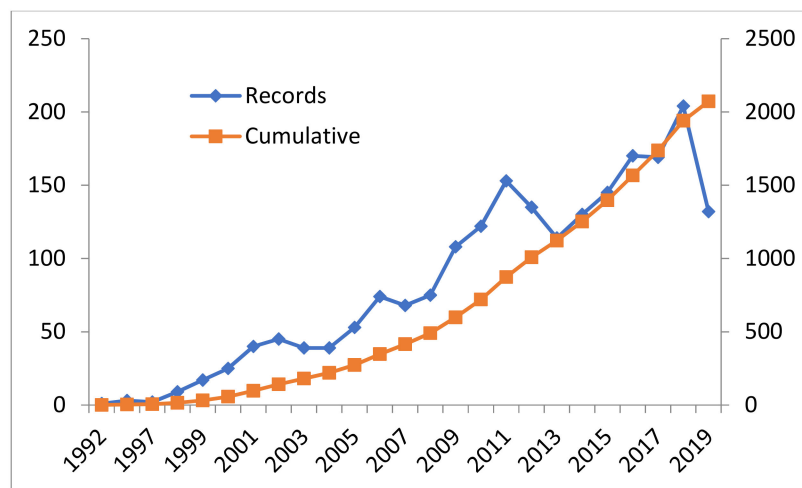
Figure 1. The time distribution of knowledge innovation literature.

3.2. Space-Distribution

CiteSpace IV can reflect the number of published papers, the cooperation and the centrality through the "ring" among some countries. The size of the rings represents the number of posts, and the outermost purple circle represents the centrality (the wider it is, the greater the centrality). Country and Institution were selected as network nodes. The extraction objects of data were Top50, and the pathfinder algorithm was adopted for the visual analysis of the sample data. According to the map of the visual network shown in Figure 2, the papers in this field mainly come from four clustering groups: the United States, China, Spain and the United Kingdom. Based on Figure 1, from the perspective of the number of published papers at each node, the United States (383 articles) and China (358 articles) have a much larger contribution to the literature output in this field, accounting for 18.5% and 17.3% of the aggregate number. This is much higher than for other countries, and it is followed by developed countries such as Spain, United Kingdom, Italy, Canada and Australia.
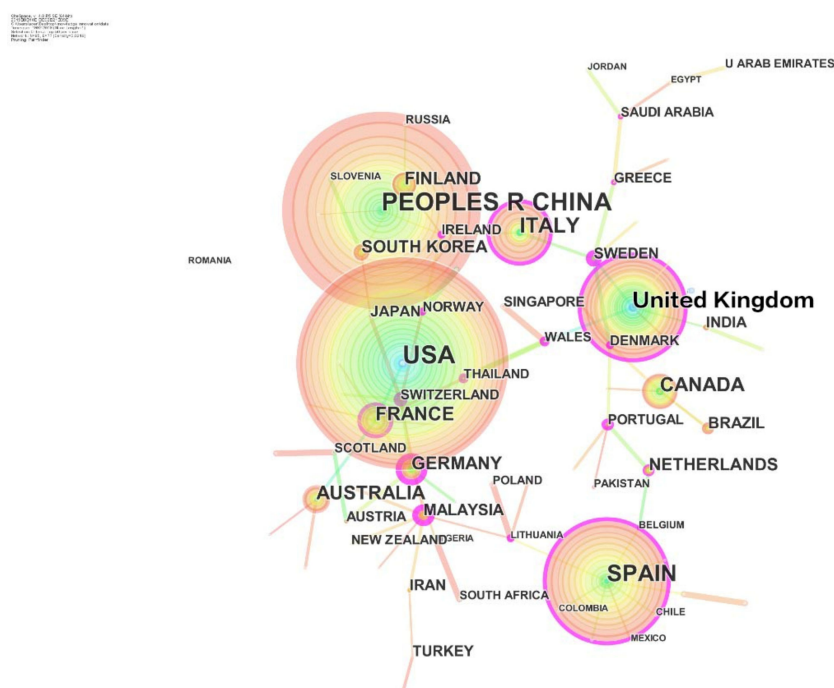
Figure 2. Distribution network map of the knowledge innovation research of nations and institutions.

But Switzerland is the most central of the entire network, indicating that Switzerland has direct or indirect partnerships with many countries in the co-existing network, such as the United States, France, and Japan. The representative of mainland China is Xi'an Jiaotong University (12 articles) and Shanghai Jiaotong University (12 articles). In the area of Hong Kong, Macao and Taiwan, the representatives are National Guoli University (18 articles) and Hong Kong Polytechnic University (14 articles). As the country with the largest output of academic papers in the field of knowledge innovation, the United States has its own research institutions, which are mainly distributed in the education system. The representatives include the Pennsylvania Federal Higher Education System (25 articles) and the University of Texas University System (19 articles). Similarly, the representative research institutions in the UK include Cambridge University (12 articles) and Manchester University (19 articles). Other representative research institutions are the Lappeenranta University of Technology (26 articles), the University of Valencia, Spain (22 articles), and the University of Murcia, Spain (20 articles). Among these representatives, the Pennsylvania Federal Higher Education System, the Lappeenranta University of Technology, and the University of Valencia, Spain, have become the core global institutions that drive research on knowledge innovation and promote international cooperation in this field.

3.3. Journal Distribution

From the number of posts and the frequency of citations (as shown in Table 2), the Journal of Knowledge Management leads the field of knowledge innovation as the top-level journal of knowledge management, and the related papers represent the research frontiers in this field. In addition, the International Journal of Technology Management and Knowledge Management Research Practice magazines are the core journals in the field of knowledge innovation, and present many representative research results in this field.

Table 2. The distribution of the journals (TOP10).

Journals	Citations
Journal of Knowledge Management	186
International Journal of Technology Management	84
Knowledge Management Research Practice	77
Journal of Business Research	46
Industrial Management Data Systems	38
Management Decision	37
Sustainability	37
International Journal of Information Management	36
Expert Systems with Applications	34
Technovation	32

Besides, when identifying core journals in a field, it is necessary to pay attention to the number of posts and the journals with a centrality and high frequency of citations. Figure 3 shows a visual result based on the analysis of sample data of co-citations using CiteSpace IV. It is worth noting that, in terms of centrality, among the top seven journals, the Journal of Management, the Academy of Management, and the Harvard Business Review are the bridge between researchers and business managers. The content of the journals focuses on the practice and application of management science. It can be seen that the theory of knowledge innovation has received attention from many scholars and business managers.
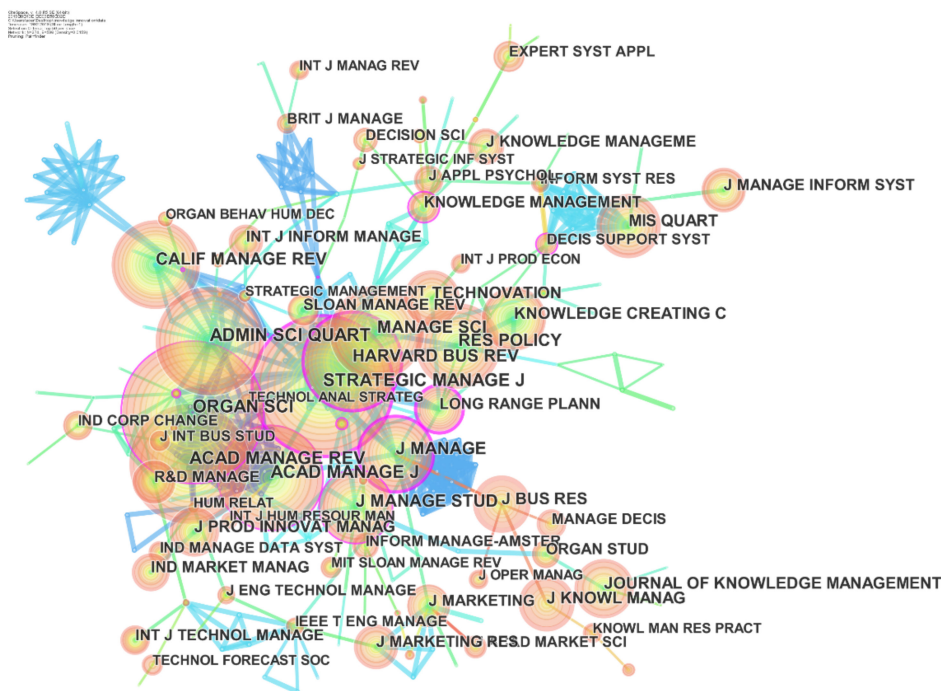
Figure 3. Knowledge innovation research on citation.

4. Analysis of the Evolution Path on Knowledge Innovation Research

CiteSpace IV bases itself on co-cited literature in order to generate a research evolution map and display the knowledge base and frontier of a domain research in the form of a time zone. Then, it can master the key achievements of knowledge innovation research and the development of the whole field. The time interval is set to 1992–2019, the network node selects the cited reference, and the threshold value is set to (2, 2, 20), (4, 3, 20) and (4, 3, 20). The search path is an adopted algorithm (pathfinder). The display mode is timezone. The result of CiteSpaceIV is shown in Figure 4.
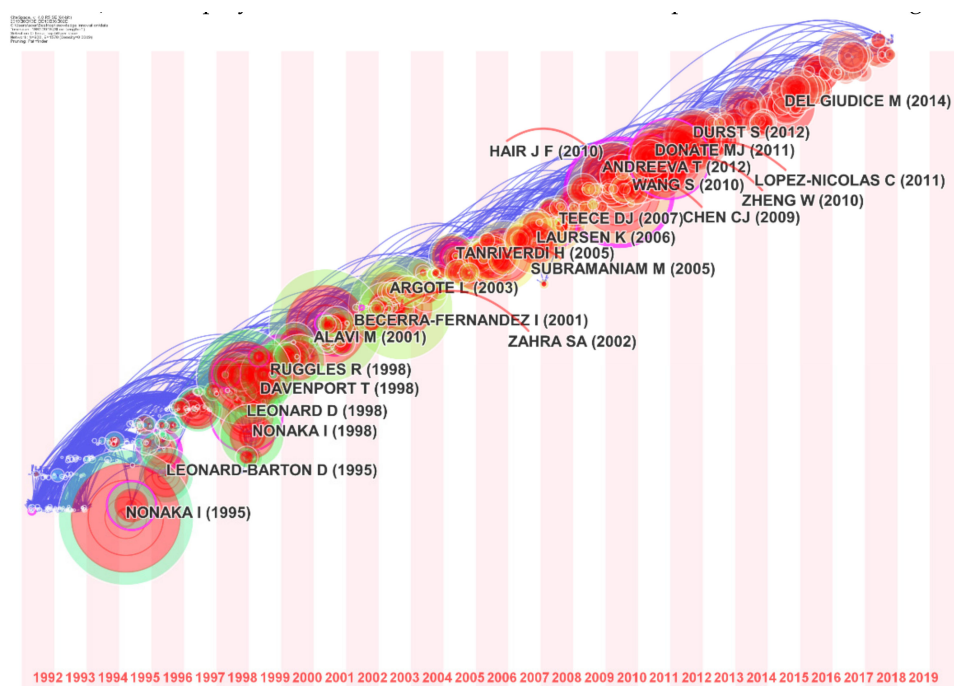

Figure 4. The knowledge map of knowledge innovation on an evolution path.

From Figure 4, we can identify the key research findings in the field of knowledge innovation, which can represent the evolution of the frontiers of knowledge innovation research. These key research results include the following. In 1995, The knowledge-creating company: How Japanese companies create the dynamics of innovation [1] is the pioneering work in the field of knowledge innovation. Professor Nonaka proposed the knowledge conversion model: the SECI model, which could demonstrate that knowledge innovation activities would sacrifice the short-term efficiency of enterprises, but that they would improve the long-term performance of enterprises. Then, it could build a framework for knowledge innovation research. Therefore, this work has become the most frequently cited document in the field of knowledge innovation.

In 1998, Davenport [15] proposed that the company's sustainable advantage comes from its collective knowledge, how to effectively use what they know, and how to easily acquire and use new knowledge. In 2001, Alavi [2] proposed that information technology plays a decisive role in knowledge innovation. In 2002, Zahra [16] proposed that knowledge innovation can create the potential of the firm, and used the model to analyze companies' potential and realize the conditions that affect the competitive advantage of enterprises. In 2009, Chen [17] proposed that knowledge management capabilities had a relationship between human resource practices and innovation performance, which further enriched the theoretical connotation of knowledge innovation for human resource management.

In 2012, through the review of knowledge management research, Durst [18] proposed that knowledge identification innovation, knowledge storage innovation and knowledge utilization innovation can improve a firm's performance and a firm's competitiveness. In 2014, Del Giudice [19] proposed that knowledge innovation is the focus of knowledge creation, differentiation and evolution, thus forming the result of the value creation of internal cooperation and competition. For a further development of Figure 4, the research evolution path of knowledge innovation can be summarized as follows. The research object moves gradually from the macro enterprise level to the micro level. Research hotspots gradually lead the research path from an internal knowledge innovation system to an inter-organization of knowledge innovation.

5. Visual Analysis of Hotspots in Knowledge Innovation Research

This paper uses Citespace IV to get a high frequency and high centrality of keywords, across years, related to knowledge innovation research. From the figure, there are two nodes with the highest frequency in the knowledge map: innovation and knowledge management. If there is a higher level of keyword centrality, it can reflect a stronger mediating role in the knowledge network. Based on Table 3, competitive advantage is taken as the central purpose of knowledge innovation, which is the priority of the research center, and centrality is at 0.4. Keywords such as information, knowledge, communication, cooperation, and industry are behind. According to the keywords' frequency and centrality in the knowledge map, the research hotspots of knowledge innovation focus on knowledge innovation performance, knowledge innovation strategy, enterprise knowledge innovation and cooperative knowledge innovation.

Table 3. The high frequency of knowledge innovation and centrality keywords.

Rank	Keywords	Year	Frequency	Rank	Keywords	Year	Centrality
1	innovation	1996	1142	1	competitive advantage	1997	0.4
2	knowledge management	1996	1139	2	information	1996	0.33
3	performance	1998	579	3	knowledge	1998	0.22
4	firm	1998	419	4	communication	1999	0.22
5	management	1998	314	5	collaboration	1999	0.2

Table 3. *Cont.*

Rank	Keywords	Year	Frequency	Rank	Keywords	Year	Centrality
6	absorptive capacity	2000	302	6	industry	1996	0.19
7	capability	1999	287	7	competence	1999	0.15
8	perspective	2000	279	8	management	1998	0.13
9	model	1998	249	9	absorptive capacity	2000	0.13
10	technology	1996	234	10	performance	1998	0.12
11	system	1996	231	11	capability	1999	0.11
12	organization	1996	217	12	technology	1996	0.11
13	competitive advantage	1997	211	13	market orientation	2003	0.11
14	strategy	1996	208	14	acquisition	2000	0.11
15	network	1996	201	15	university	2003	0.1
16	impact	2005	197	16	organization	1996	0.09
17	product development	2001	191	17	information system	1998	0.09
18	research and development	2002	165	18	learning	2003	0.09
19	knowledge	1998	165	19	alliance	1999	0.09
20	firm performance	2007	147	20	auto industry	2001	0.09

A further analysis of the keywords can cover the analysis of the academic hotspot. It uses the LLR algorithm from CiteSpaceIV to extract keywords, and the system generates high-frequency-keyword clustering maps. If the modularity = 0.7373 > 0.3, and the mean silhouette = 0.5819 > 0.5, this can indicate that the clustering is good and has a clear outline. The specific information of knowledge clustering for Figure 5 is shown in Table 4. The two largest clusters are cluster 0, for management, and cluster 1, for research and development management. The number of documents in the clusters are 31 and 28, respectively.

Table 4. Ten automatic clusterings of the keywords' co-occurrence network.

Number	Nodes	Contour Value	Average Year	Title of LLR
0	31	0.828	2001	Management
1	28	0.738	2001	Research and Management Development
2	27	0.843	2003	Practice Community
3	25	0.925	2001	Global Competitiveness
4	23	0.936	2003	Knowledge Management
5	23	0.886	2001	Innovation Management
6	23	0.761	2002	Strategic Alliance
7	20	0.81	2003	Knowledge Network
8	17	0.846	2002	Product Innovation Management
9	16	0.89	2004	Inter-organizational on Knowledge Transfer
10	10	0.866	2004	Tacit Knowledge on Sharing Intention
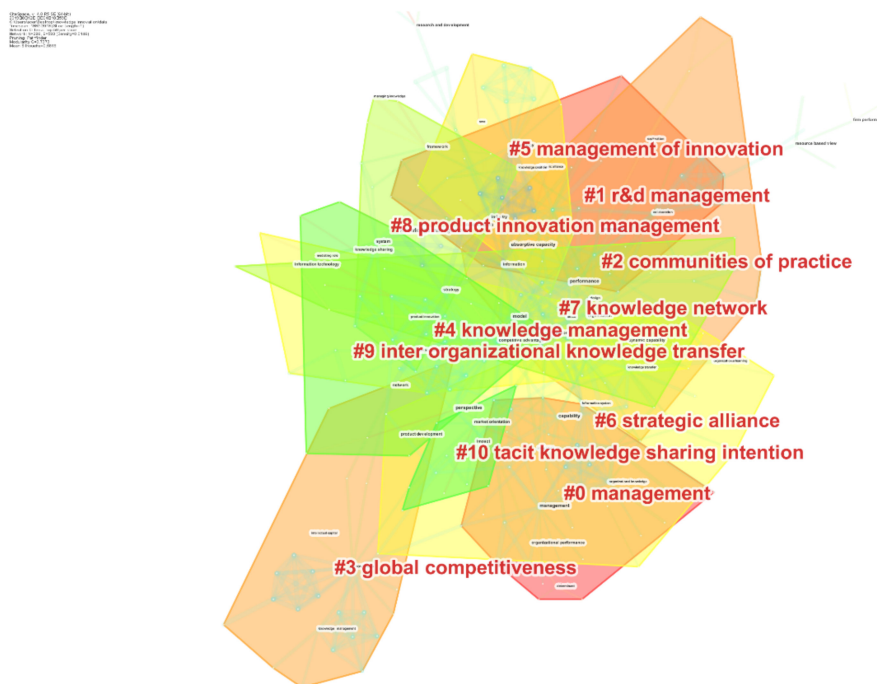
Figure 5. The clustering map of the knowledge innovation keywords.

Based on the analysis of the map, this paper clarifies the research hotspots of knowledge innovation. The author divides it into the following four points of research, which clearly show the knowledge structure and development of knowledge innovation.

5.1. The Basis of Research of Knowledge Innovation System in Enterprise

This type of research mainly includes #1, #4, #5, and #8 from the cluster map. Representative keywords include knowledge management system, information system, electronic performance support system, knowledge creation, best practice model, organizational learning network, and so on.

Lopez [20] pointed out that, by improving enterprise innovation and the process of distribution, organizations construct internal and external networks and organizational methods to update an enterprise's innovation. Yu [21] pointed out that the use of knowledge management systems and organizational learning was identified as an intervention process for transferring strategic direction into true innovation capabilities. Lin [22] used the theory of innovation diffusion to empirically study the impact of three context variables (organizational readiness, expected benefits, and organizational learning capabilities), which can reflect that they can have an effect on the applicability of knowledge management systems. Zelaya-Zamora [23] argued that management influences and resources can interact significantly. They then have an impact on an organization's knowledge creation capabilities, which in turn are positively correlated with the organization's innovation performance.

Liyanage [24] proposed the concept of research management, namely the generation of intellectual capital, which can promote the development of future enterprises and new products. Yang [25] proposed Electronic New Product Development (E-NPD) in a new knowledge economy, defined as customer relationships, business processes, IT applications, and integration with knowledge management systems, which are necessary for innovation through new business models.

5.2. The Basis of a Research Knowledge Innovation Model for Innovation Cooperation among Enterprises

This type of research mainly includes #2 and #7 in the clustering map. The representative keywords include communities of practice, knowledge network, theory of innovation resource synergy, social network and communication pattern. Nieves [26] argues that there is a complex relationship between all social networks and the ability of their members to create knowledge. Ritala [27] presents

antecedents of external knowledge sources for R&D and innovation. They investigated the impact of corporate strategies that had an effect on the search scope of their open knowledge. Yang [28] argued that knowledge acquisition and dissemination played an important role between vendors and their suppliers. They also pointed out that strategic organizational behavior (namely cost and innovation orientation) relieves the relationship between knowledge management and supply chain integration. Lin [29] focused on numerical research on the knowledge innovation and diffusion process of four representative network models: the ruling network, small world network, random network and scale-free network. They showed that the scale-free network is optimal for a knowledge transfer performance. Magnier-Watanabe [30] showed that the social network has improved efficiency to some extent, such as getting knowledge or increasing the number of business contacts. More importantly, the study shows that when using intranet-based social networks, the social capital and higher innovation can show a higher social network force. Zhang [31] pointed out how the knowledge gained from alliance partners affects organizational knowledge creation, which in turn leads to innovation performance.

5.3. The Basis of Research on the Knowledge Innovation Path on Knowledge Sharing Among Firms

This type of research mainly includes #9 and #10 in the cluster map. The representative keywords include inter-organizational knowledge transfer, communication model, tacit knowledge sharing intention, explicit knowledge sharing intention and explicit knowledge sharing intention. Through case studies, Currah [32] explores the competitiveness of emerging retail multinationals, which increasingly rely on mobilizing and integrating knowledge from multiple locations to adapt retail portfolios and rapidly changing businesses to the environment. Simonin [33] explores the role of the causal blurring nature of knowledge in the process of knowledge transfer among strategic alliance partners. This involves an empirical analysis of the ambiguity of knowledge, implicitness, assets specificity, past experience, complexity, partner protection, cultural differences and other factors, which have a lasting impact on the knowledge of multinational firms. Wee [34] found that SME owners (rather than employees) are the key sources and creators of knowledge, as well as the only drivers of knowledge management processes. In SMEs, knowledge creation takes the form of innovation in order to meet customer needs via customized solutions. Knowledge sharing is carried out through cross-functional overlapping roles and promoted through a close physical relation in open workspaces. Knowledge reuse usually occurs in public under the permission of common sense. Leal-Rodriguez [35] proposed a conceptual model to test whether the role of learning can adjust the relationship between knowledge strategy and innovation: the depth and scope of the knowledge base would contribute to developmental innovation. Mura [36] found, first, that knowledge-sharing behavior has a positive impact on the innovation of the information shareholder in terms of the propensity and ability to promote new ideas. Second, sharing best practices and mistakes are two different drivers of personal innovation. Third, the individual's perception of social capital has a corresponding adjustive impact on the relationship between knowledge sharing and innovative behavior.

5.4. The Basis of Research on Knowledge Innovation Management for Global Strategy Orientation

This type of research mainly includes #3 and #6 in the clustering map. The representative keywords include global competitiveness, sustainable competitive advantage, knowledge transfer, and international joint venture. Chang [37] pointed out that new knowledge is gained through knowledge diffusion activities that occur after the knowledge innovation. Science and technology workers have been established on the basis of informal social networks and the existence of a common culture. Mascitelli [38] proposed a comprehensive framework that identifies tacit knowledge as an important source of sustainable competitive advantage and offers guidance to companies to develop tacit knowledge enhancement strategies. Koch [39] proposed the concept of knowledge relevance, by which a product development team specializes in relevant scientific or technical fields, and is considered to be an important mediator of the relationship between operational procedures and innovation performance. If the development teams perform well, the performance of the innovative

companies will also do well. Volberda [40] discusses absorptive capacity to demonstrates the impact on knowledge innovation and competitive advantage. Wang [41] believes that the majority of knowledge has a positive impact on innovation. With a higher absorptive capacity in the company, the relationship between knowledge attributes and innovation performance is more significant. Knowledge attributes and absorptive capacity are two decisive determinants of a corporation's innovation performance.

In order to more vividly show the development stage and trend of knowledge innovation within the research field, this paper obtains the keyword-cluster time-zone map of this field through the CiteSpace IV software. Figure 6 shows that most of the research in the field of knowledge innovation from the past 27 years can be roughly divided into four stages, as follow: from 1991 to 2001, from 2002 to 2008, from 2009 to 2014 and from 2015 to 2019. From 1991 to 2001, scholars mainly studied knowledge innovation of firms from a systematic view. From 2002 to 2008, they mainly studied knowledge innovation among organizations. From 2009 to 2014, they mainly studied knowledge innovation among firms. From 2015 to 2019, they focused on the micro-level of the performance of knowledge innovation.
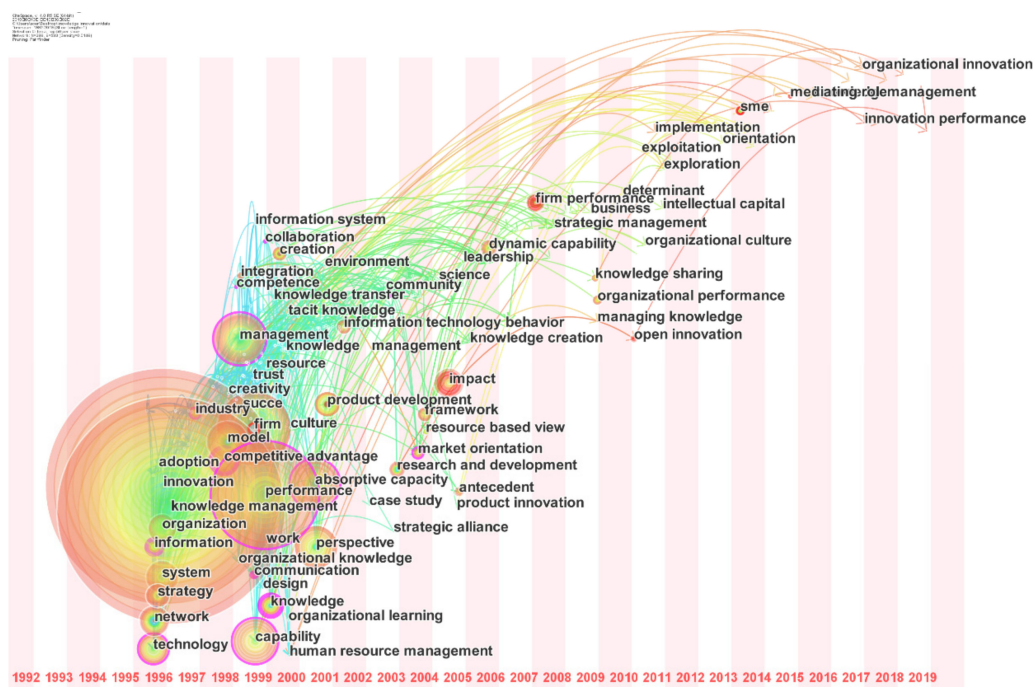

Figure 6. The clustering timeline map of knowledge innovation keywords.

6. Conclusions

This paper utilizes CiteSpace IV software to acquire further information mining, in order to sort out and analyse knowledge innovation research from a multi-dimensional, time-sharing and dynamic perspective. Following this, it could further rationalize the distribution status, development trends and hotspots of knowledge innovation research. There is no doubt that it provides empirical evidence regarding the international frontier of knowledge innovation. The main conclusions are as follows.

The United States, China, and the United Kingdom are the leading international countries in the field of knowledge innovation research. The United States leads the world in terms of the volume published papers, while the United Kingdom leads knowledge innovation research in Europe. In Asia, China has the most research in the field of knowledge innovation when compared to other countries.

The core journals in the field of knowledge innovation research are defined by the volume of publications, the frequency of citations and the index of co-citation. There are academic journals, such as the Journal of Knowledge Management, International Journal of Technology Management, and

Knowledge Management Research Practice. Furthermore, there are management and practice journals, such as the Journal of management, Academy of Management and Harvard Business Review.

From a systematic view of enterprise knowledge innovation to inter-organizational knowledge innovation focused on a developmental move toward inter-enterprise cooperative knowledge innovation research, the development trend of knowledge innovation research is as follows. The research objects are increasingly diversified, and empirical research gradually replaces case studies as the main research method.

Although it is a widely studied and popular topic in the social sciences, there is no comprehensive bibliometric review that can quantitatively visualize the evolution of the field of knowledge innovation research. To address this research gap, we use the visualization tool CiteSpace IV to detect research frontiers, major topics, landmark documents, and breakthrough articles in the knowledge innovation literature. Based on this information, we analyze how the pattern of knowledge innovation research has evolved over time. In addition, we provide a future research agenda based on the current research trends. By doing so, this article gives scholars a systematic understanding of the literature and emerging trends. It also identifies the research frontiers in knowledge innovation research and provides scholars with a roadmap to advance these research frontiers.

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