

Keyword Co-occurrence Analysis of Research on Innovation Ecosystem Studies

Pengbin Gao [†], Jianxin Zhao, Xue Li

School of Economics and Management, Harbin Institute of Technology at Weihai, Shandong Weihai 264209, China

[†]Email: gaopengbinhit@163.com

Abstract

The aim of the paper is to identify and explore leading thematic areas within the research field related to innovation ecosystem. Based on data from the Web of Science database, the keywords frequency and its co-occurrence frequency pair were analyzed, and the theory of mapping knowledge domains was used to visualize the keywords co-occurrence network in innovation ecosystem to make further research of the heated issues. The findings indicate that the research scope involved in innovation ecosystem research is broad, and research content focus on micro and macro levels. According to the results of keywords co-occurrence analysis of different stages, innovation, network, knowledge, strategy, open innovation, value creation are the most important issues to innovation ecosystem research, given their position and role in the research network. The paper generates the added value mainly from the point of view of theory development.

Keywords: *Innovation Ecosystem Research; Knowledge Mapping; Visualization Analysis; Keyword Co-Occurrence*

1 INTRODUCTION

Economic globalization and market integration make the competitive environment more complex and changeable. Along with the blurring of industrial boundary and enterprise boundary, the innovation paradigm presents a systematic, ecological and dynamic trend. At the same time, Silicon Valley ecosystem, P&G's open innovation platform and Apple's innovation ecosystem have made the great success, which makes the innovation ecosystem become an important topic concerned by the theoretical study and industrial practice.

With publications on innovation ecosystem research proliferating in recent years, there have been efforts to elucidate the status of research in the field. A majority of such efforts have been devoted to qualitative reviews, including understanding the concept and theory, and analyzing the structure and evolution of system. Moreover, more efforts have been devoted to use the bibliometric analysis method to conduct the quantitative research, including clarifying the trends, mainstream and hotspots and current situation^[1], highlighting the most influential paper, to discuss the concept, and to conclude six research streams^[2], analyzing the important scholars, influential journals and key literature in the field of innovation ecosystem^[3], and explore the thematic differences^[4]. There were found few records indicating the use of a keywords analysis for mapping the research field. However, both of them are centred on static aspects rather than mapping the whole research field from the dynamic view.

Therefore, making an attempt to fill the identified gap, the aim of this paper is to replicate the aforementioned study in order to identify and explore leading thematic areas within the research field related to innovation ecosystem. Moreover, the emerging topics in the field will be mapped.

2 METHODOLOGY

2.1 Data Set

Data set to be analyzed in this paper was retrieved from Web of Science (WoS), which provides a comprehensive citation search and supports reference cross-disciplinary research. So the WOS Core collection database was chosen

as the source for literature related to innovation ecosystem research. During exploratory topic searches for related literature, it was observed that many records included “innovation ecosystem” in the abstract and/or author-provided keywords. Therefore, the sample used in this study was retrieved from the WoS core collection and filtered using “innovation ecosystem”, “innovation ecosystems”, “ecosystem of innovation” and “ecosystems of innovation” in both the title and topic; for maximum recall, the time-frame covered the years from 1980 to 2019; and it included the document types of Article and Review. The data were extracted in October 5th, 2019. Finally, a total of 451 articles were retrieved and selected as the analysis sample.

Based on the statistical analysis of the retrieval data according to the annual number of papers published, the number of innovation ecosystem research papers published from 2002 to 2019 was showed in Fig.1. Although there were only a few papers before 2010, the number of papers has been a steady increase since 2010 and the quantity reached to a high tide in 2018, which indicate that innovation ecosystem research has gradually become the focus in the research field, and this trend is constantly strengthening.

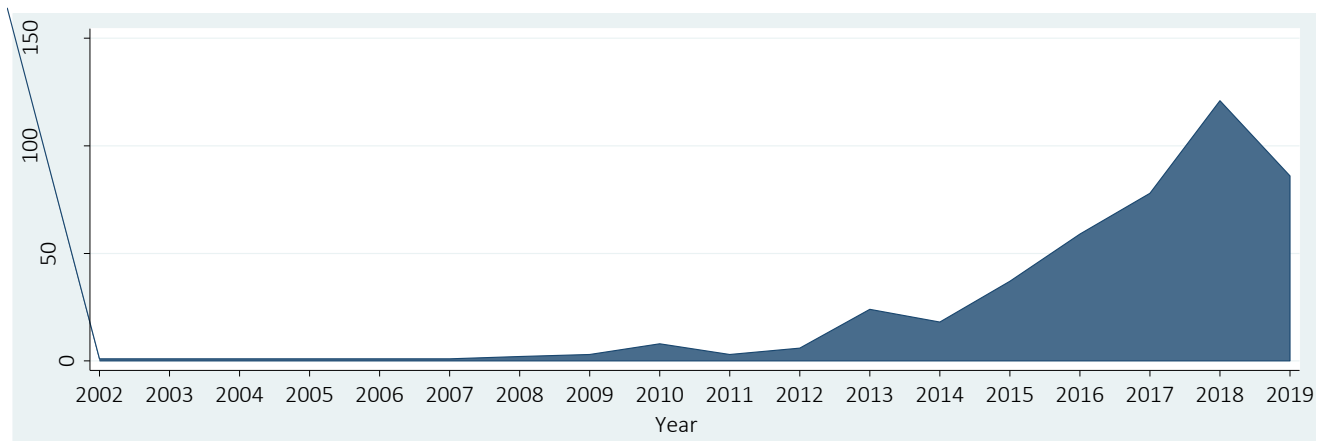


FIGURE 1. YEAR DISTRIBUTION OF INNOVATION ECOSYSTEM PUBLICATIONS

2.2 Research Method

Knowledge visualization has already become a new research field that combined graph theory, bibliometrics, statistics and many other theories. It materializes the abstract knowledge, making them easy to observe, as a result, helping more people to grasp the knowledge better. Co-word analysis draws upon the assumption that a paper’s keywords can give an adequate description of content. Its effectiveness in identifying and revealing the underlying collaborative structure and patterns has been proven by many previous studies in other fields^[5-6].

We depict the keywords network of research, in which the nodes are the keywords while the links represent the co-occurrence of these keywords. VOSviewer is a software tool for constructing and visualizing bibliometric maps. Unlike most computer programs that are used for bibliometric mapping, VOSviewer is especially useful for displaying large bibliometric maps in an easy-to-interpret way, and pay more attention to drawing and clustering^[7].

3 RESULTS

3.1 Keyword Description Analysis

Due to the process of disposing keywords, we came by 2002 keywords after extracting authors’ keywords and keywords plus from 451 articles and data mining them. Along with observing the frequency of the keywords data, we have found out that the percentage of frequency beyond 10 is about 0.32%, among which the percentage of the keyword that only appear once is about 76.17%, frequency that under 5 is about 93.41%.

From Table 1 we can see that the keyword frequency faces sharp decline in innovation ecosystem. In the past 18 years’ research, innovation ecosystem is mainly focused on innovation, network, knowledge, strategy, technology, performance, ecosystem, system, value creation, open innovation, entrepreneurship, dynamics and collaboration.

Figure 2 shows the overall evolution of top 20 keywords over time. In general, whereas the number of flows in Figure 2 fluctuates, top 20 keywords are indicated, in agreement with the results above.

TABLE 1 THE FIRST 42 KEYWORDS IN FREQUENCY

No.	Keyword	Frequency	No.	Keyword	Frequency
1	innovation ecosystem	161	22	perspective	26
2	innovation	112	23	policy	25
3	network	67	24	impact	24
4	knowledge	66	25	capability	23
5	strategy	64	26	evolution	23
6	technology	60	27	platform	22
7	performance	58	28	organization	21
8	ecosystem	53	29	university	21
9	system	53	30	framework	19
10	value creation	51	31	competition	19
11	open innovation	42	32	governance	19
12	industry	41	33	smart city	18
13	firm	40	34	triple helix	17
14	research-and-development	39	35	market	16
15	management	39	36	firm performance	16
16	entrepreneurship	36	37	business model	16
17	business ecosystem	32	38	integration	16
18	model	32	39	city	15
19	dynamics	31	40	challenges	15
20	collaboration	30	41	business	15
21	science	28	42	absorptive-capacity	15

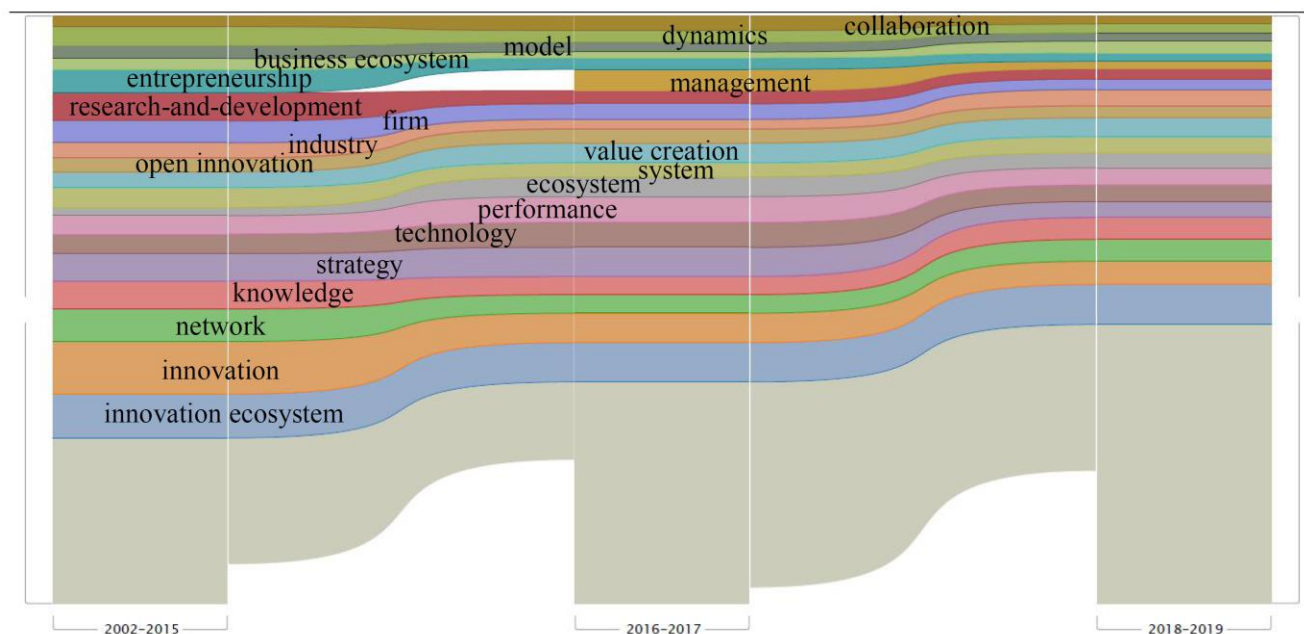


FIGURE. 2 EVOLUTION OF DISCIPLINARY COMMUNITIES OVER TIME

3.2 Keyword Co-occurrence Analysis

Generally, searching keywords for research papers is a convenient way to retrieve data for studying a research field. In order to explore the change of research themes in innovation ecosystem research from 2002 to 2019, the eighteen-year study period was broken into three sub-periods according to the number of articles: 2002-2015 (107), 2016-2017 (137) and 2018-2019 (207). The study collected all the keywords from the sample articles to conduct co-word analysis. Using the VOSviewer software, this paper visualized the relationships among the keywords and

understood the changes of research topic overtime. The results are showed in Figure 3, 4 and 5. Cluster analysis of high-frequency keywords of each period is presented in Table 2. The results of keyword co-occurrence pairs of each period are show in Table 3, 4 and 5.

TABLE 2 CLUSTERS OF HIGH-FREQUENCY KEYWORDS RELATED TO INNOVATION ECOSYSTEM

Period	Community	Number of keywords	Representative keywords
2002-2015	C1-1	9	Science-11; network-10; performance-9; technology-8; research-and-development-8; open innovation-7; university-5; model-5; perspective-4
	C1-2	8	Strategy-12; firm-8; dynamics-6; ecosystem-5; capability-5; business ecosystem-5; collaboration-5; value creation-4
	C1-3	6	Innovation-29; knowledge-10; entrepreneurship-8; industry-5; market-5; growth-4
	C1-4	6	Governance-8; evolution-6; organization-5; complexity-4; modularity-4; economy-4
	C1-5	5	innovation ecosystem-26; system-6; service innovation-4; information technology-4; business model-4
2016-2017	C2-1	20	Innovation-38; system-18; firm-14; research-and-development-13; dynamics-12; entrepreneurship-12; impact-11; industry-9; policy-9; model-9; organization-8; university-8; science-8; technology transfer-7; framework-6; design-5; triple helix-5; governance-4; knowledge transfer-4; sustainability-4
	C2-2	19	innovation ecosystem-48; strategy-26; network-20; ecosystem-19; knowledge-17; value creation-16; collaboration-11; business ecosystem-7; capability-7; firm performance-7; business model-6; market-6; case study-5; ecology-5; platform-5; competitive advantage-5; creation-5; orchestration-4; knowledge management-4
	C2-3	10	Technology-21; performance-21; perspective-12; evolution-10; integration-7; cooperation-5; service ecosystem-4; dominant logic-4; service innovation-4; service-dominant logic-4
	C2-4	8	Management-21; open innovation-15; business-9; smart city-7; competition-6; product development-5; emergence-4; city-4
2018-2019	C3-1	25	Knowledge-39; system-29; dynamics-13; clusters-11; absorptive-capacity-11; smart city-9; city-9; organization-8; university-8; innovation system-8; design-6; transition-5; entrepreneurial ecosystem-5; technology transfer-5; community-5; big data-5; information technology-4; regional innovation-4; smes-4; living lab-4; innovation policy-4; opportunity-4; insights-4; intermediaries-4; methodology-4
	C3-2	18	Performance-28; strategy-26; business ecosystem-20; policy-15; framework-12; perspective-10; dynamic capabilities-9; growth-7; sustainability-7; business model-6; creation-6; ecology-6; technological innovation-6; china-5; economy-5; digital ecosystems-4; science park-4; co-evolution-4
	C3-3	16	Network-37; collaboration-14; impact-11; science-9; complexity-8; integration-7; co-creation-6; case study-6; information-5; business-5; dominant logic-5; value cocreation-4; commercialization-4; experience-4; knowledge ecosystem-4; service ecosystem-4
	C3-4	15	Technology-31; value creation-31; industry-27; firm-18; capability-11; competition-10; challenges-9; competitive advantage-7; evolution-7; service-6; strategic alliance-5; market-5; cooperation-4; architecture-4; product development-4
	C3-5	14	innovation ecosystem-87; innovation-45; ecosystem-29; model-18; entrepreneurship-16; platform-15; triple helix-11; firm performance-8; governance-7; start-ups-5; multilevel perspective-5; technological change-4; regional innovation ecosystem-4; network externalities-4
	C3-6	11	open innovation-20; research-and-development-18; management-15; future-6; quadruple helix-6; knowledge management-6; knowledge transfer-5; exploration-4; network analysis-4; entrepreneurial university-4; social network analysis-4

TABLE 3 THE FIRST 10 KEYWORD CO-OCCURRENCE PAIRS IN FREQUENCY(2002-2015)

No.	Keyword co-occurrence pairs	Frequency	No.	Keyword co-occurrence pairs	Frequency
1	Innovation-innovation ecosystem	7	6	Innovation ecosystem-service innovation	3
2	Entrepreneurship-innovation	5	7	Capability-innovation	3
3	Innovation-knowledge	4	8	Capability-innovation ecosystem	3
4	Innovation ecosystem-knowledge	4	9	Research-and-development -science	3
5	Innovation ecosystem-strategy	3	10	Industry-innovation	3

Identified high-frequency keywords can be categorized into 5 communities corresponding with the areas of research interest in the field during 2002-2015 in Figure 3. Cluster 1 (marked in red) was related to science, network and model in macro level. Cluster 2 (marked in green) was focused on strategy, capability and value creation in firm level. Cluster 3 (marked in blue) dealt with innovation, entrepreneurship and knowledge in industry level. Cluster 4

(marked in yellow) was related to governance, evolution and economy in macro level. Cluster 5 (marked in purple) was focused on innovation ecosystem, service innovation and business model in firm level.

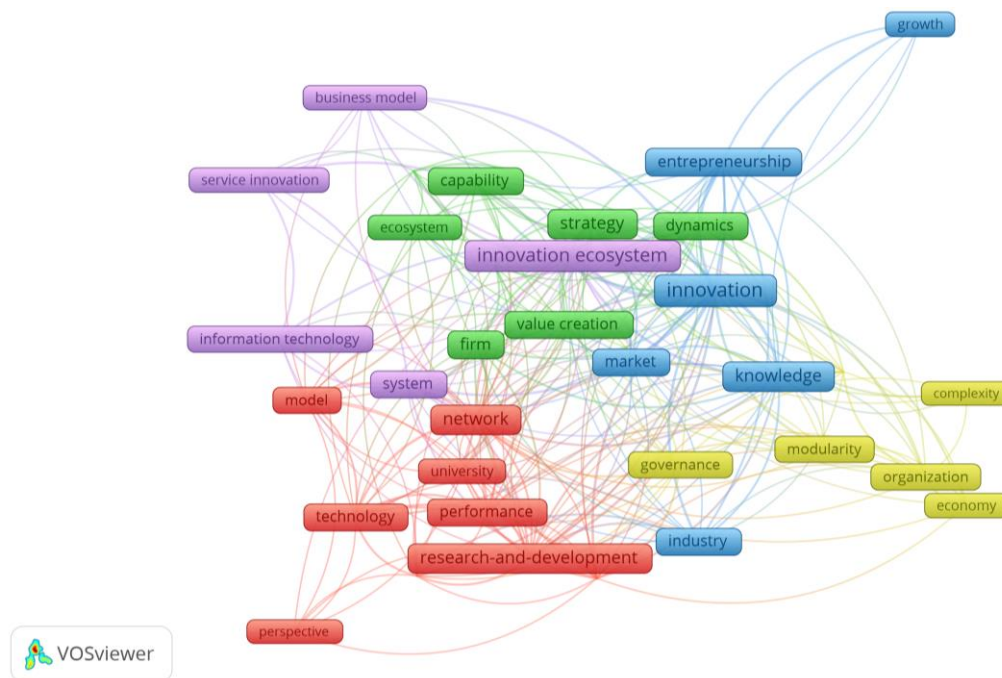


FIGURE 3. CO-OCCURRENCE NETWORK OF HIGH-FREQUENCY KEYWORDS (2002-2015)

TABLE 4 THE FIRST 10 KEYWORD CO-OCCURRENCE PAIRS IN FREQUENCY(2016-2017)

No.	Keyword co-occurrence pairs	Frequency	No.	Keyword co-occurrence pairs	Frequency
1	Innovation ecosystem-strategy	13	6	Innovation ecosystem-network	10
2	Innovation-innovation ecosystem	11	7	Network -strategy	9
3	Innovation ecosystem-value creation	11	8	Ecosystem-innovation	9
4	Innovation ecosystem-technology	11	9	Innovation ecosystem-performance	8
5	Innovation ecosystem-management	10	10	Entrepreneurship-innovation	8

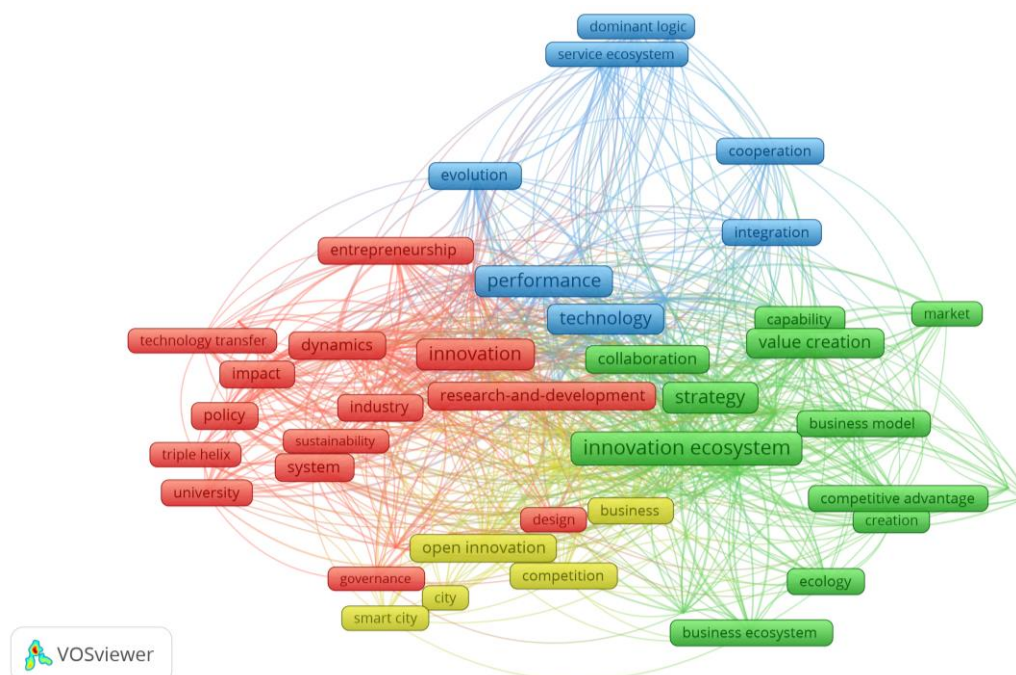


FIGURE 4. CO-OCCURRENCE NETWORK OF HIGH-FREQUENCY KEYWORDS (2016-2017)

Identified high-frequency keywords can be categorized into 4 communities corresponding with the areas of research interest in the field during 2016-2017 in Figure 4. Cluster 1 (marked in red) was related to innovation, entrepreneurship, industry, university, policy and system in macro level. Cluster 2 (marked in green) was focused on strategy, capability, business model and value creation in firm level. Cluster 3 (marked in blue) dealt with technology, performance, evolution and service in firm level. Cluster 4 (marked in yellow) was related to open innovation, management and city in macro level.

TABLE 5 THE FIRST 10 KEYWORD CO-OCCURRENCE PAIRS IN FREQUENCY(2018-2019)

No.	Keyword co-occurrence pairs	Frequency	No.	Keyword co-occurrence pairs	Frequency
1	Innovation ecosystem-value creation	19	6	Innovation ecosystem-network	14
2	Innovation-innovation ecosystem	16	7	Industry-innovation ecosystem	14
3	Innovation ecosystem-knowledge	16	8	Innovation ecosystem-technology	14
4	Innovation ecosystem-strategy	15	9	Innovation ecosystem-model	12
5	Innovation ecosystem-system	15	10	Innovation ecosystem-performance	12

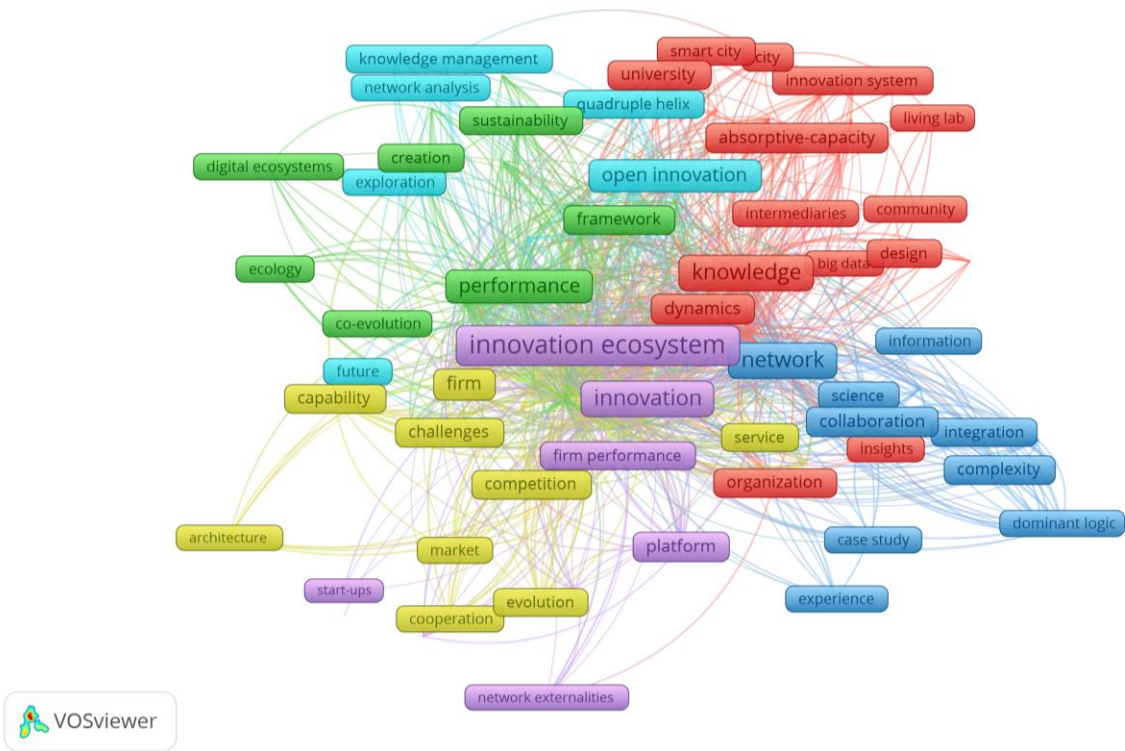


FIGURE 5. CO-OCCURRENCE NETWORK OF HIGH-FREQUENCY KEYWORDS (2018-2019)

Identified high-frequency keywords can be categorized into 6 communities corresponding with the areas of research interest in the field during 2018-2019 in Figure 5. Cluster 1 (marked in red) was related to knowledge, system, dynamics, cluster,design, community, university, city and absorptive-capability at macro level. Cluster 2 (marked in green) was focused on strategy, business model, co-evolution and creation in firm level. Cluster 3 (marked in dark blue) dealt with network, collaboration, integration, complexity and case study in macro level. Cluster 4 (marked in yellow) was related to capability, value creation, evolution and service in firm level. Cluster 5 (marked in purple) was related to innovation, firm performance, platform and network externalities in firm level. Cluster 6 (marked in sky blue) was related to open innovation, knowledge management, exploration, network analysis and quadruple helix in macro level.

4 CONCLUSIONS

The objective of this study is to reveal the hotspots and development research trends of the field of innovation ecosystem based on the publications covering the time period from 2002 to 2019. VOSviewer software was

performed for co-occurrence analysis of the keywords of 451 articles retrieved from WOS database.

The results were summarized as follows. The most popular keywords in innovation ecosystem between 2002 and 2019 are: “innovation”, “network”, “knowledge”, “strategy” and “technology”. Further, those findings suggested that the research hotspots in innovation ecosystem evolved from micro-level analysis such as “strategy”, “capability”, “value creation”, “open innovation”, “business model” and “knowledge” to more macro-level analysis such as “city”, “university”, “industry”, “network”, “collaboration”, “science”, “policy”, “governance” and “triple helix”.

The findings in this study are helpful in understanding the knowledge structures. The present results have implications for research and practice, which is helpful in focusing on one specific research domain. However, future study is also suggested to expand the scope of data source in covering more diversified research domain and building a more solid social network structure in innovation ecosystem, such as document co-citation, journal co-citation and author co-citation.

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AUTHORS

¹**Pengbin Gao** was born in Shannxi Province on September 9th, 1979. He received the B.S. degree in Business Administration from Harbin Institute of Technology, Harbin, China, in 2001 and the M.S./Ph.D. degree in Technology Economy and Management from Harbin Institute of Technology, Harbin, China, in 2005 and 2013, respectively. He is currently an Associated Professor with the School of Economics and Management, Harbin Institute of Technology, Weihai, China. His research interests include innovation management and technology management.

²**Jianxin Zhao** was born in Liaoning Province on February 4th,

1996. She received the B.S. degree in Human Resource Management from Huazhong Agricultural University, Wuhan, China, in 2019. She is currently pursuing her master's degree in Business Administration in Harbin Institute of Technology, Weihai, China. Her research interests is innovation management.

³**Xue Li** was born in Shandong Province on February 7th, 1996. She received the B.S. degree in Business Administration from Harbin Institute of Technology, Weihai, China, in 2017. She is currently pursuing her master's degree in Business Administration in Harbin Institute of Technology, Weihai, China. Her research interest is innovation management.